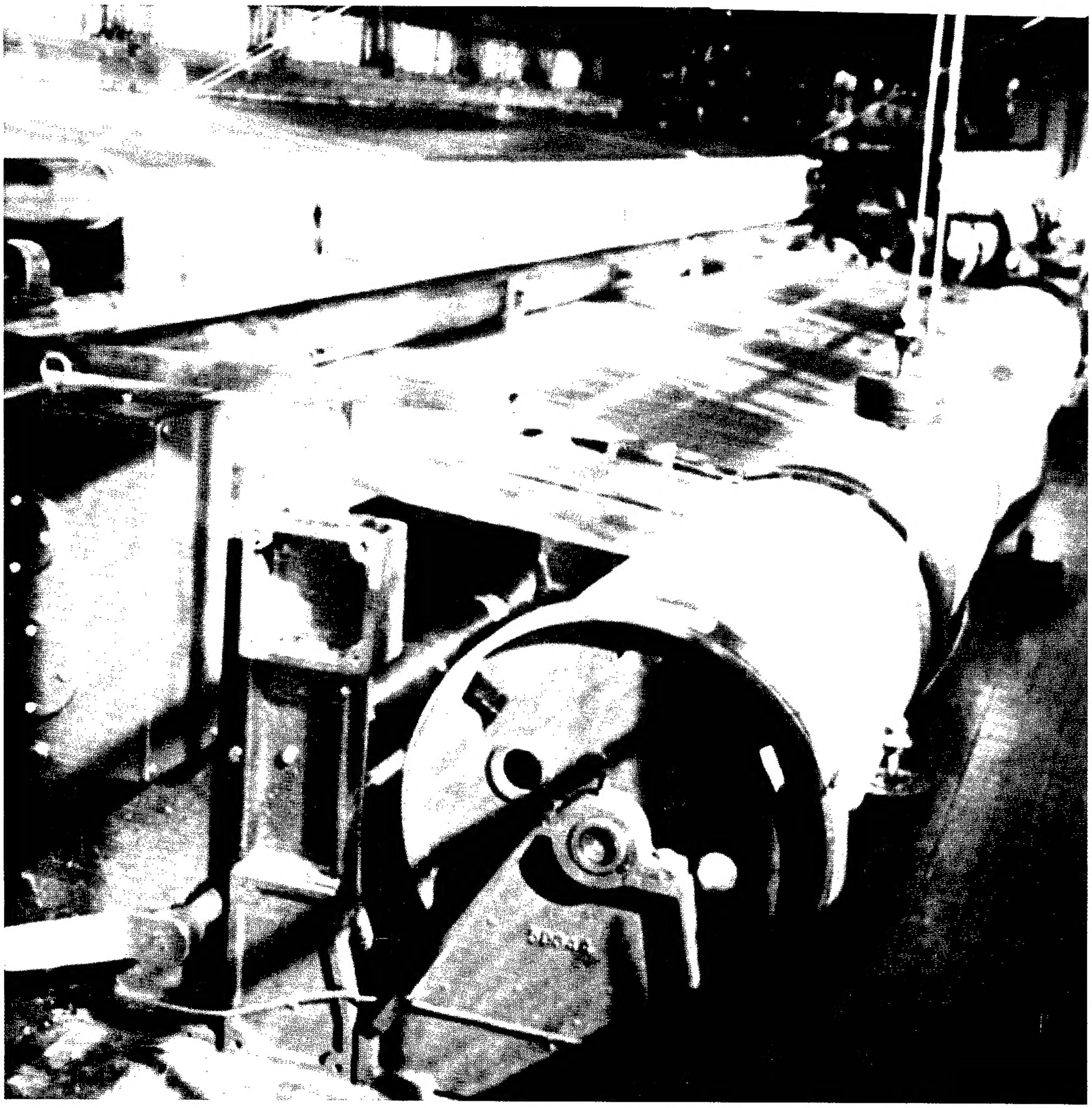
US Army

ManTech Journal

Achieving A Breakthrough

Volume 7/Number 3/1982



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Contents

ABOUT THE COVER:

Large collapsible fuel tanks can be woven on looms such as this one which can handle tubular fabrics up to 90 feet wide. In work sponsored by the U.S. Army Mobility Equipment Research and Development Command, multiple harness wide fabric looms have been developed that are capable of producing such seamless tubular fabrics. Weaving of a tubular fabric is similar to the production of flat fabrics, except that there are two sets of warp yarns, one set to form the top of the tube and the other set to form the bottom. The filling yarns are inserted through the top set of yarns on one pass across the loom and then through the bottom set of yarns as the shuttle returns. It is critical to minimize weaving irregularities at the two edge turnaround points. For further information, contact Richard W. Helmke, (703) 664-5176.

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Comments by the Editor

RAYMOND L. FARROW

It has been interesting for those of us involved with the production of the U.S. Army ManTech Journal to note that one of our associates—Stephen Robinson, who has served on the magazine's staff as Technical Consultant for the U.S. Army Armament Materiel Readiness Command—has been selected to manage the recently announced $235 million renovation of facilities at Rock Island Arsenal. Steve's replacement as Technical Consultant on the magazine's Advisory Staff is Mr. W. Dennis Dunlap. We have been pleased to be associated with Steve during the past three years and appreciate very much his help and cooperation in setting policy for the Journal. As Chief of Project Rearm at Rock Island Arsenal, he has promised the magazine staff a close look at the modernization program which he is overseeing, and we plan to carry an article on the project in the near future.

This issue of the Journal features the largest number of Brief Status Reports that we have carried to date, in response to the wishes of our readers who have been universal in their requests for more brief, current reports on ongoing projects in the Army's MM&T program. The preponderance of the briefs in this issue are on munitions and weapons projects of the Munitions Production Base Modernization Agency which are being carried out at various Army Commands. We will report on a more homogeneous mix of projects of all types of MM&T work in future issues, now that we have nearly completed a comprehensive update on all current Army projects.

The article on proving the functionability of Army fuzes simultaneous with their production is an example of the large savings in dollars possible from a well conceived, efficiently implemented mantech program. The Harry Diamond Laboratory staff involved should be commended for their accomplishment and should be proud of the economic impact of the program.

Some very sophisticated production technologies were put into effect by the Army's Aviation R&D Command on the manufacture of the T700 turbine nozzle. This article outlines the development of a technique that uses computer assisted electrical discharge machining along with area measurements via automated optical devices. The report should be of interest to many fabricators who are faced with the challenge of producing components with complex surfaces to extremely close tolerances.

One of several very short articles in this issue of the Army ManTech Journal is featured on page 8. This report is about another Electronics Command project conducted by Jim Kelly, who has authored previous articles for the Journal. The project established important guidelines to be followed in the manufacture of the highly reliable beam lead devices that have presented a challenge to production engineers for some time.

Numerous cost advantages from producing forgings by high energy rate forging can now be realized following the completion of a project on this technology by ARRCOM.

The economic leverage existent from the fact that so many components of heavy combat equipment are made by forging means that enormous cost savings will result from the determination of how best to use this technology. The article on page 17 highlights this work.

More efficient telemetry of artillery projectiles is the result of the successful completion of a project described in an article on page 22 in which the Harry Diamond Laboratories developed a new compact crystal controlled L-band transmitter that is much more rugged than past such devices.

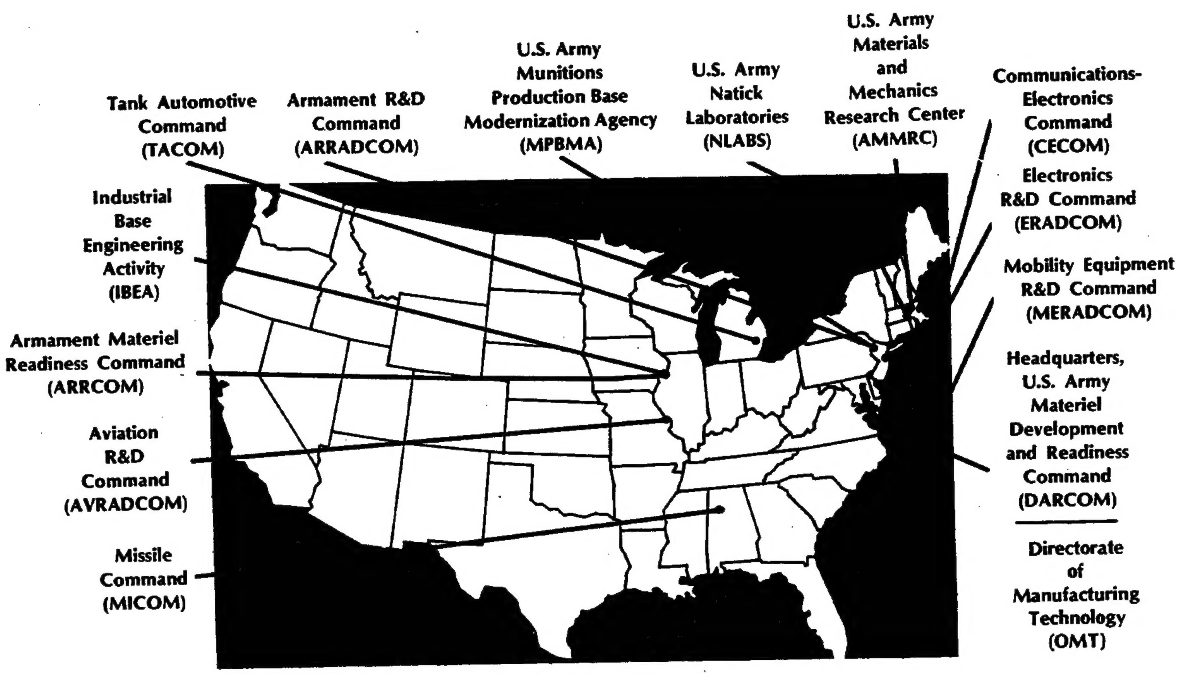
The high cost of over specification of surface finishes on gun components was determined by a project conducted at Watervliet Arsenal which established firm data regarding cost factors related to this type of production. The study was most significant, pinpointing areas where designers could reduce costs of production markedly simply by specifying only those surface finishes that are necessary for the functioning of a particular part, rather than "playing it safe" by over specifying requirements beyond those needed. This project's findings will make dramatic cost savings possible when taken into consideration at the design stage.

Substantial cost savings and improved mechanical properties will result in missile primary structures produced as monolithic structures by internal shear forging, as indicated by the findings of a mantech project sponsored by the Army Missile Command. Components of greater strength result from the thermomechanical treatment, and improved dimensional stability and decreased residual stresses have been observed, pointing to continuing improvement in product. The near net shape components fabriccated with this technology contribute to sharp cost savings.

Arc plasma spray technology has been put to excellent use on phase shifter fabrication by the Army's electronics agencies, as described in a pair of articles on pages 31 and 35. In the first article, the remarkable flexibility of the arc plasma spray technique lends itself well to the production demands of small batches of lithium ferrite phase shifters whose design may continually be modified. An economical method of fabrication that can accommodate design changes easily is a perfect match with the component characteristics.

The second article of this duo describes how arc plasma spray techniques make possible economical production of millimeter wave phasors whose designs are characterized by extremely close tolerances and whose ultimate performance is affected critically by the uniformity of the component's structure.

DARCOM Manufacturing Methods and Technology Community

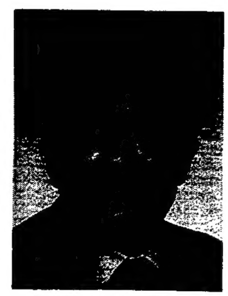


Prototype Presents Fewer Problems

Production Validation of Electronic Fuzes

HARRY E. HILL, JR. is Chief, Fabrication Technology, U.S. Army Harry Diamond Laboratories, Adelphi, Maryland. He received his B.S. in Mechanical Engineering from Duke University in 1967 and has done graduate work in Systems Engineering at George Washington University. He has been involved with R&D and/or mechanical fabrication throughout his professional career.

FRANK L. TEVELOW is a project engineer in the Harry Diamond Laboratories Environmental Test Branch currently evaluating the effects of logistical transportation vibration on fuzes and developing criteria for random vibration test specifications to replace swept sinusoidal test procedures. His entire career has been at HDL, where he has been involved in the design, testing, and evaluation of fuzes. From 1960 to 1967 he did basic research on the interaction of X-band radiation with shock tube generated ionized gases. From 1974 to 1978 he was technical assistant to the Chief, Research and Engineering Support Division, coordinating and overseeing the operational and architectural design specifications for relocation of the division's facilities from Washington to new quarters at Adelphi, Maryland. Mr. Tevelow received his B.S. in Physics from George Washington University in 1957.



JOHN J. FURLANI is Chief of the Mechanical Technology Branch at the Harry Diamond Laboratories, Adelphi, Maryland, where he has acquired over 30 years of experience in the research, development, and production of electromechanical and electronics fuzing and other ordnance systems. He is an engineering graduate from the City College of New York and has attended graduate school at Maryland University. He is a member of ASME, SME, and ADPA. He has authored or coauthored more than 30 technical reports and has several patents relating to fuzing, safing, and arming.

Savings of over 17 million dollars are projected as a result of the successful development of a system of validating electronic fuze quality during production in a program carried out at the Army's Harry Diamond Laboratories for the U.S. Army Electronics Research and Development Command. The methodology was the result of a deliberate, systematic approach to the long standing problem of efficiently proving the functionability of the Army's artillery fuzes when produced at high rates.

Economic Justification

An economic analysis was made comparing the predicted costs of fuzes in production under the current system versus these costs with the Prototype Validation Facility (PVF) in operation. This analysis was based on the assumption that the utilization of the PVF during development will provide a head start toward the later production phase. This was estimated to result in a 10 percent reduction in unit production cost. Over an 11 year period, 11 projects were considered.

The analysis concluded that a total present value of savings amounted to 17.03 million dollars, a savings to investment ratio of 2.32, and a rate of return on investment of 22 percent. These figures, of course include the cost of construction, equipment purchase, and operating expenses.

The principal objective of this study by the Harry Diamond Laboratories for the U.S. Army Research and Development Command was the definition of a facility that could manufacture and test prototype electronic fuzes using advanced state of the art production techniques. This objective has been realized. Also, the technologies and equipment necessary to apply them have been enumerated, the facility has been laid out in detail, and a multiyear plan for implementation of the findings of this study has been developed.

NOTE: This manufacturing technology project that was conducted by Harry Diamond Laboratories was funded by the U.S. Army Electronics Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The HDL Point of Contact for more information is Mr. John J. Furlani, (202) 394-3124.

Semiconductor Research

Semiconductor R&D personnel at HDL have been producing devices for electronic fuzes, radars, and optical systems for many years. They have been innovators in semiconductor technology; for example, they developed the two step reduction process for mask making and the use of the step and repeat camera for generating large arrays. Much of their current work is directed toward the development of radiation hardened semiconductor devices for military use. The trends developing in this area are the increased use of silicon monolithic devices and the integration of fuze functions. The emphasis will be on bipolar and complementary metal oxide semiconductors. The facilities proposed will allow for a practical transition between demonstrating feasibility and ensuring producibility. The area will have precise environmental control to minimize contamination, an ion implanter for the accurate placement of impurities, injection molded plastics encapsulating for lower costs, and semiautomatic equipment for process control.

Electromechanics

Electromechanical experts identified two separate areas where improvements are required. The first area identified was the support area of mechanical parts fabrication. The use of low cost fabrication techniques such as stamping, coining, casting, sintering, and molding is desirable in many electromechanical components, including safety and arming (S&A) devices. These capabilities are necessary for component fabrication so that assembly and test operations will be performed on similar items. Because of stringent safety requirements, extensive testing is required of S&A mechanisms, and process changes often require the repetition of these tests.

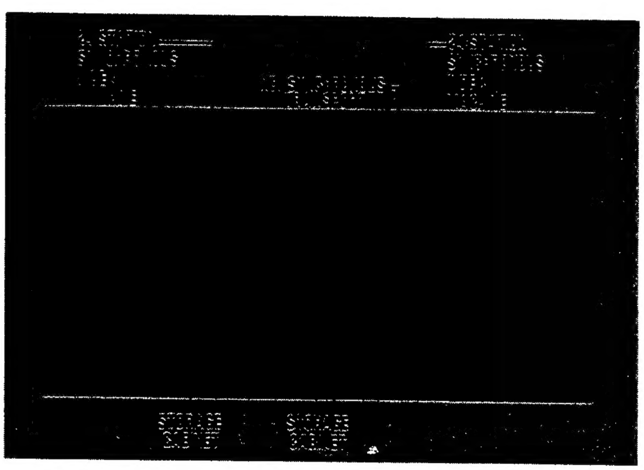


Figure 1

The second area identified was mechanized assembly, testing, and inspection. This is integral to the design of the mechanisms and has the potential of large savings. Currently, these are labor intensive areas and the work is done by hand. The emphasis will be on mechanization and merging of the assembly and test operations. Mechanization will also offer improved safety in the fabrication area (Figure 1).

Thick film microelectronic fabrication and assembly (Figure 2) is a technology recently applied to electronic

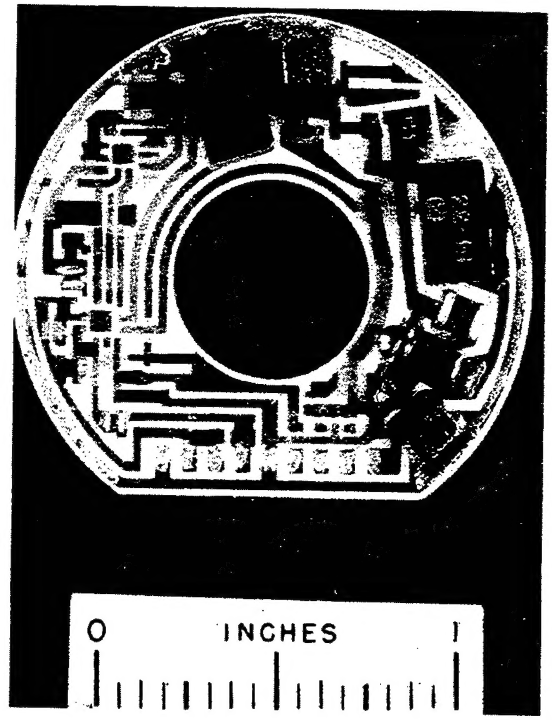


Figure 2

fuze circuits. It is not only an emerging technology, but one that currently is expensive for military systems. The increasing use of multifunction fuzes and the increasing interest in fuzing smaller munitions are causing greater use of this technology. Problems that need to be worked on in this area are

(1) The print and fire parameters that allow the needed fine line conductor patterns and achieve resistor trimming
(2) Adoption of active resistor trimming compatible with high production rates

(3) Automatic wire bonding with a single visual alignment
(4) Development of low cost packaging techniques for the ordnance environment.

The printed wiring board fabrication area will allow for additive and subtractive board processing and multilayer board fabrication. Printed wiring boards will continue to be used in electronic fuzes when space permits and in other applications because they are rugged and relatively inexpensive. In addition, printed circuit board techniques are used in the fabrication of antennas and rf stripline circuitry. This area will provide the capability for fabricating printed circuits in large arrays which reduce handling and are desirable with automatic insertion equipment. New processes will also be introduced such as the additive process, which uses less copper and results in less waste, and multilayer board fabrication, which increases circuit density and allows printed circuit techniques to be used on more complex circuitry.

The electronic board assembly area will emphasize machine insertion of components. The relatively low cost of printed circuit boards compared to thin and thick film circuit methods and the proven ruggedness of these subassemblies in the ordnance environment virtually assures their continued use. Modern hand assembly stations and machine insertion will both be used. The high density of components in some electronic applications requires partial or complete hand assembly. Whenever possible, machine insertion will be used to decrease hand labor requirements for these assemblies. The use of large array circuits for machine insertion, mass soldering, and automatic lead cutting all effect circuit topology. Circuits assembled in this facility will have demonstrated compatibility with all of these mass production techniques.

Fuze Power Sources

Most of the research and development that extends the state of the art in power supplies for electronic fuzes is conducted by the Government. Safety requirements, limited space, and the extended shelf life of electronic fuze power supplies make them unique. Four power supply types meet these requirements: liquid reserve (Figure 3), thermal reserve, turboalternator, and fluidic generator. The technology base for these is highly specialized and radically different from the commercial battery industry. The power supply area is already heavily committed to prototype power supply fabrication. The equipment that power supply personnel are proposing will augment what they already have with the emphasis on techniques and processes that are very close to or can be readily adapted to those used by commercial manufacturers. In addition, materials will be evaluated for their suitability to satisfy performance criteria and for their adaptability in fabricating the required power supply.

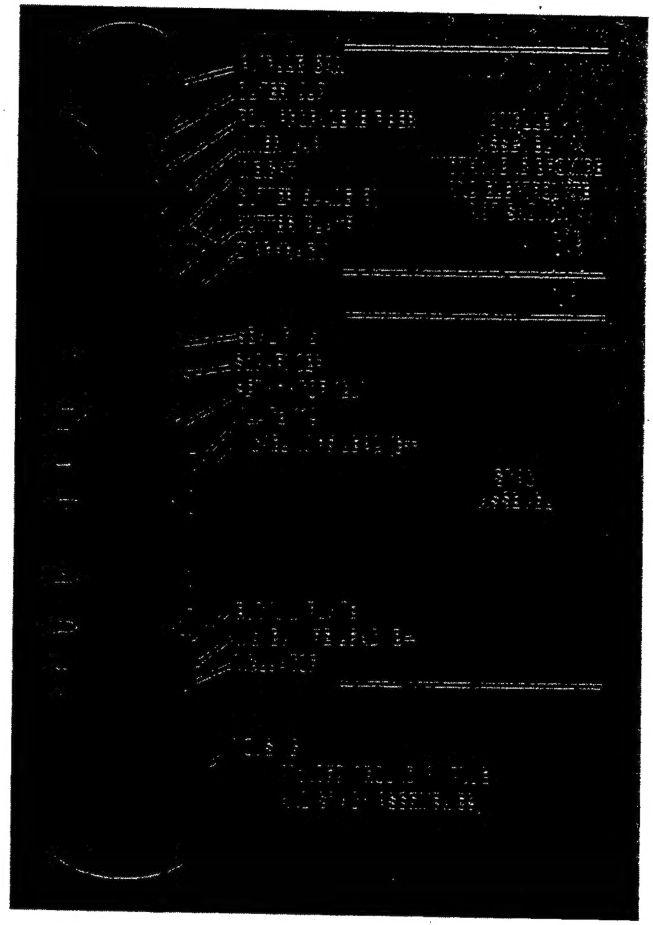


Figure 3

Environmental, Electronic Testing

The goal of the environmental test area is to achieve accelerated conventional environmental tests. This is necessary so that the environmental testing can keep pace with the increased rates of mechanized assembly. If production rates increase, the current level of confidence can be maintained, and if production rates remain constant, the testing level of confidence can be increased. The high cost of field tests and the time delay between fabrication and field testing make accelerated environmental testing desirable. Field tests will not be eliminated, but accelerated environmental testing will provide a quick reaction screening of production units and allow for early detection of faulty production units. The PVF can provide production

items. This will result in improved correlation of test results to final field performance. These efforts—combined with recent advances in the technology of simulated environmental testing—have the potential of replacing field testing, after initial correlation, with simulated environmental testing. The electronic test area is where the proper functioning of the fuze is validated. Experience has shown that on-line testing of electronic fuzes (particularly the radiating type) is a cricital factor in the production process. Design and fabrication of such equipment has accompanied each fuze development with the specifications and often the equipment itself being given to the production contractor for inclusion on the production line. Numerous measurement and inspection techniques already exist and are in use in automatic fabrication at assembly lines for commercial mechanical and electronic items. Many of these methods are directly applicable to fuze manufacture and can be incorporated into an automatic line with a high degree of confidence. Other aspects of fuze testing, however, particularly special conditions applying to radiation type proximity fuzes, have no direct counterpart in high production items on the commercial market. It is on the second type of testing that the prototype validation facility will concentrate. Recent advances in microprocessors and related automatic equipment have permitted an expanded and more sophisticated role for such equipment. Mechanical handling, automatic cycling of tests, and marking of tested fuzes will be included. Minicomputer control of the microprocessor controlled test station will provide flexibility and real time data acquisition.

Electronic Assembly

The electronic assembly area examined two problems: the final assembly of electronic fuzes and methods of nonstandard fastening. The relative merits of rotary or synchronous machines and nonsynchronous transfer machines were considered in some detail, and it was concluded that rotary tables were better, but for final fuze assembly the nonsynchronous system is advantageous and for this application such a system is proposed. Two types of nonstandard fastening methods were proposed: ultrasonic and laser. This equipment will be used to support both the electromechanical and the power supply areas. Several ultrasonic bonders were proposed to provide the needed range of frequencies and power levels. Two laser systems were also proposed: a 200 to 500 W yttrium aluminum garnet (YAG) or ruby laser and a 1 to 5 kW carbon dioxide laser. The ability of this type of equipment to concentrate on small areas minimizes the possibility of damaging other areas or components on the work piece. Both technologies are being adopted by industry for high rate quality production because of their controllability and a resultant low reject rate. The mechanical parts fabrication area will operate in support of the rest of the facility. The primary deficiencies cited by development groups were the lack of powdered metal and die casting technology. The addition of these capabilities accounts for most of the effort. Special design considerations, safety requirements, and physical properties of the parts require the use of production like parts during development testing. Because of the large inventory of equipment and extensive use of screw machine parts, two screw machines were specified. These parts are not the most desired, because of dependence on foreign equipment, but until proven alternatives are developed they will continue to be used in quantity in electromechanical devices. The current numerically controlled machine tool and plastic molding equipment is considered necessary and sufficient for proper operation of the overall facility. A general shop and inspection area is also necessary to support the facility. These capabilities are also enumerated.

Computer Support Important

There are a number of areas within the Prototype Validation Facility where computer support is required. This support will be provided by a combination of minicomputers and intelligent terminals that will tie into existing computer facilities at HDL. Management will use these facilities for scheduling, inventory control, and costing information. Computer aided design and manufacturing will be coordinated with the NC equipment throughout the facility. Portable terminals will provide real time data acquisition from operating equipment and online test setups. These data can then be analyzed and/or used as inputs to simulation programs. Since the PVF will have single pieces of equipment when the production facility may have many, the cost of end items in production will rely to some extent on the ability to simulate the proposed production facility on computers. Once each of the areas was defined, the individual areas were integrated into one combined facility. This involved the removal of duplications and the addition of areas overlooked in the separate chapters.

Work Level vs. Staffing

Of real concern is the problem of maintaining the PVF capability when the work level is low. This problem was considered early in the study and was recognized as a critical factor in assessing the practicality of the PVF. It was concluded that if an element of the PVF required the permanent assignment of specialists for operation then it was not practical for inclusion. As a result, each of the several

study groups was informed that they should approach the problem with the assumption that the PVF activity could be maintained with existing staff. Further, if specialized knowledge was required for the operation of certain types of equipment, it would be obtained by training and not by recruiting additional staff. This was considered to be a reasonable limitation since equipment already existed and was being used to fabricate prototypes. With additional training, existing staff could become proficient in the operation of the equipment required for the PVF. Further, since the emphasis was being placed on producibility, more prototypes would be fabricated on the new and less on the old equipment. Thus, the overall workload would not be significantly increased.

Mobilization Readiness Achieved

There is strong rationale to support the conclusion that a prototype design—using industrial type fabrication methods made on production like equipment that is validated by various test methods before release for production engineering—will present fewer problems and fewer scheduling delays, and will result in a cheaper, more reliable end product. Computer support, on-line test data, and simulation testing will also provide documented test data packages against which laser production run units can be measured. Because of the various production options, HDL personnel would be used efficiently by shifting people among the various areas as work loads change. This will provide a group of people, well versed in the various production areas, that will be able to go to contractor plants, consult with and advise the contractor in setting up production lines, pinpoint problem areas, and assist generally. At least one individual will be responsible for overseeing and coordinating all operations, including value engineering, design to cost, quality assurance, reliability, and development of prototype test data packages. Another individual will act as the library and conduit for collecting, staying abreast of, and disseminating state of the art and technological advances relating to product engineering and automation. The PVF group will form a reservoir of inhouse expertise that will stay abreast of the latest advances in production technology areas pertinent to electronic devices, including fuzing. They will thus be in a position to advise Army headquarters staff regarding electronic technology production, thus assuring a strong defense posture complemented by mobilization readiness.

Skepticism at the Beginning

This study was the joint effort of nine branches at HDL. The distribution of work was recommended by a Steering Committee that convened to review this project. The committee then decided that the project should be managed by the Engineering Support Branch and that tasks related to specific component areas would be delegated to the appropriate branches within HDL. It was felt that this method would provide for the broadest input to the project within HDL at the lowest cost. The initial reaction of several branches to the prototype validation facility (PVF) concept was skepticism. Skeptical or not, they began to examine how they were doing things, what industry was doing, the costs of changing designs after testing, and problems that now occur in the manufacturing of electronic fuzes. Attitudes gradually changed, and skeptics became advocates. The conversions first occurred within each area of expertise and gradually expanded into overlapping areas. Not all technical groups support the need for the complete facility. This is primarily because the problems peculiar to one area are not understood by those in other disciplines. It is the consensus of those involved that the evolved plan (Figure 4) should be implemented and that all elements should be included. The prototype validation facility represents a reemphasis of production aspects during development. This had been considered during development, but the PVF now provides the tools for verification of producibility. Not only will the tools be provided, but the development personnel will be actively involved, allowing them to benefit from this experience. Knowledge gained during prototype fabrication will be used to aid the management of contractors' efforts during development and later during the production phase. Further, production techniques specific to a particular design will be passed along to the contractor to reduce transition time from development to production.

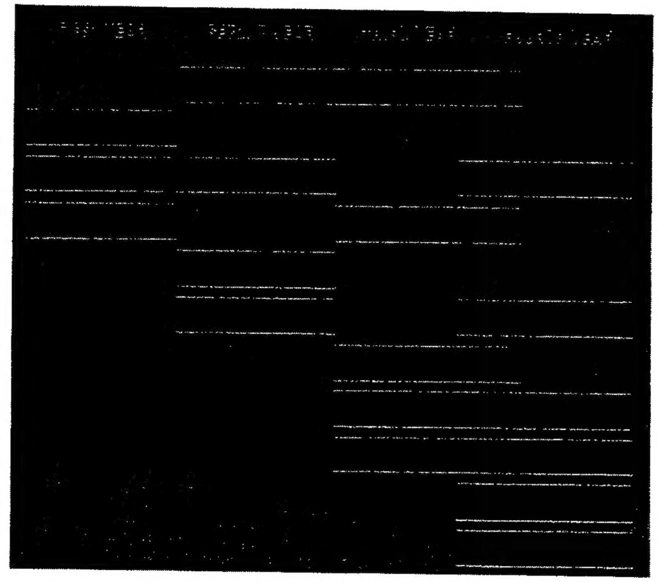


Figure 4

Three Part Program Focus

Improving T700 Nozzle Manufacture

JONATHAN PRATCHER is a Project Engineer at the U.S. Army Aviation Research and Development Command, where he works on all categories of testing and inspection activities for the manufacturing technology group. He has worked at AVRADCOM for four years, following eight years of work at McDonnel-Douglas. He received his B.S. in Industrial Technology from Tuskegee Institute in 1971.

Photograph

Unavailable

Computer assisted EDM, cooling flow measurements by IR, and automated optical area measurement have been utilized to improve T700 turbine nozzle manufacturing. In a program conducted by the General Electric Company, Aircraft Engine Group, in Lynn, Massachusetts and Evendale, Ohio, this work was sponsored by the U.S. Army Aviation Research and Development Command.

Programmable EDM Reduces Time

The first part of this work consisted of using the current EDM process and adding a new concept utilizing a computer assisted power supply to the nozzle airfoil trailing edge cooling holes. A programmable EDM power supply will indeed reduce the cut time for the T700 trailing edge closed slot operation by one third. However, maximum machining rate obtainable could not be used due to micro cracking. Further, the reduction in planned time that can be achieved on this operation will require approximately 1250 sets to recover the investment cost.

To carry out this task effort, the Manufacturing Technology Laboratory at Evendale conducted a development program to assess the potential benefits of a programmable electrical dishcharge machining (EDM) power supply for a T700 turbine component application. A programmable EDM power supply permits the selection of a "parameter profile" which is optimum for varying machining conditions during the course of an electrical discharge machining operation. This allows minimum cut time commensurate with required geometry and surface characteristics—by machine control.

Since it would be totally impractical to attempt EDM electrical power supply variations in a production environment, the decision was made to perform the experiments at the Manufacturing Technology Laboratory.

The trailing edge cooling holes in the T700 high pressure turbine nozzle vane are close toleranced and of a size and depth which challenge existing EDM capabilities for low cost manufacture. The established electrical discharge machining practice on this application is to use constant parameters for the entire cut. These parameters are governed primarily by the machining conditions at the "entrance" and "exit" of the cut where dielectric flushing and other process requirements are marginal. The EDM cut time on this operation at the onset of this program was sixteen minutes. A different production supply introduced during the program enabled reduction of the cut time to twelve minutes. This application was, therefore, thought to be amenable to improvement with the use of a programmable power supply.

NOTE: This manufacturing technology project that was conducted by General Electric was funded by the U.S. Army Aviation R&D Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The AVRADCOM Point of Contact for more information is Mr. Jonathan Pratcher, (314) 263-1625.

The Testing and Equipment

The machining optimization tests and demonstration hardware were run on a Raycon EDM machine equipped with a Raycon programmable power supply Model CP60. The EDM head movement is controlled by a hydraulic servo and has a one inch stroke. The CP60 is built around a microprocessor which continuously monitors the system operation and issues the appropriate commands needed to implement an EDM operation. It also checks for fault conditions and operator commands and provides interface with the operator via keyboard or permanent memory unit.

In this development activity, process parameters were entered through the keyboard. The parameters which can be programmed are: sequence time, pulse time, interval time, arc level, arc suppress, short delay, servo feed, servo response, polarity, pulse, and gap extender.

A production shuttle (part holder) for EDM of T700 High Pressure Turbine Nozzle (HPTN) vane trailing edge holes was adapted to the laboratory EDM machine. Then a duplicate of the electrode guide mechanism was built and installed on the laboratory machine. Production electrodes were used for all tests and demonstration hardware. Next, preliminary trial runs were made using round electrodes and flat work pieces to verify capability to perform the planned tasks.

To establish a base for comparative results, it was necessary to verify production machining times on the CP60 power supply. The production power supplies are not the same as the laboratory supply in some respects other than the microprocessor; however, the shop times of 16 and 12 minutes per cut were approximated on the CP60.

Experiments were run in flat work pieces to optimize the EDM parameters for that portion of the cut when the electrode and workpiece are "fully engaged" and the machining conditions permit the maximum penetration rate and lower overall cut time. A series of four designed experiments were run and the results of each were analyzed using statistical techniques. Parameters for each test were then modified in directions indicated by the analysis.

Gentle parameters for EDM at the "entrance" and "exit" of the cut were determined and evaluated. These parameters are used for only a short period of time during the cut and extensive testing was not necessary. The parameters were set at "safe" values based on prior experience. The principal responses measured were net penetration rate, slot dimensions, and metallography.

Although a lot consisting of four production parts was run to verify parameters in the actual workpiece geometry, a log of twenty production parts was run with optimized parameters to demonstrate the process.

Test Results

Four separate experiments were conducted. The first—to optimize the "fully engaged" parameters—was built around the limits of the power supply capability for each controllable characteristic in an attempt to avoid guiding the test with preconceived ideas. The extreme combinations produced malfunctions in every instance, and no measurable EDM took place.

The second consisted of 32 runs and 9 factors. Statistical analysis identified that (1) servo feed, servo response, and gap extender had little effect on measured responses, (2) net travel increases significantly with increasing current level, (3) electrode wear decreases significantly with increasing time and decreasing current level, (4) electrode wear increases with interaction of pulse time and arc level, and (5) very high interval times produce very slow machining rates.

The third test showed that (1) net travel increases significantly with current level and decreases moderately with increasing arc level, (2) electrode wear increases significantly with increasing current level, (3) overcut increases significantly with increasing pulse time, current level, and servo response, (4) micro cracking is significantly affected by current level, interval time, short delay, and servo feed, (5) maximum penetration rates obtained could not be used in production due to micro cracking beyond allowable limits, and (6) optimum machining conditions for the "fully engaged" cut, based on the analysis, are as shown below with asterisks indicating recommended settings.

Optimum EDM Conditions

	Net Travel	Wear Ratio	Crack Length
Pulse	11	55	11
Interval	—	250	350
Current Level	16	10	10
Arc Level	7	9	7
Arc Suppress	7	9	—
Short Delay	—	—	3
Servo Feed	—	—	14
Servo Response	—	—	—

The last experiment consisted of machining four production parts using values intermediate to those shown to be optimum statistically. Micro examination of the parts showed redeposited material or "globules" near print limit. Recast and micro cracks were well within print

limits, and the average EDM cut time was 9½ minutes. A lot of twenty production parts was then machined using the procedure.

Cooling Flow Measurements by IR

The second part of this combined study focused on applying infrared (IR) inspection to T700 nozzle segments for the purpose of detecting blocked airfoil surface cooling holes and for the purpose of estimating cooling flow rate. Infrared inspection is based on computerized analysis of infrared thermal transient images of airfoil surfaces following a sudden injection of a cooling fluid into the airfoil. The practicality of detecting blocked surface holes was demonstrated on a very small number of parts, but the high signal-to-noise ratios obtained indicate that excellent blocked hole detection performance can be expected on larger samples of parts. The application of infrared inspection to predict airflow rates for 47 nozzle segments run twice each (94 runs total) yielded a root-mean-square prediction error of approximately 3.3% of the mean airflow rate. While this result does not meet current production accuracy requirements, several areas where the accuracy of infrared inspection can be improved are examined in this report (Figure 1).

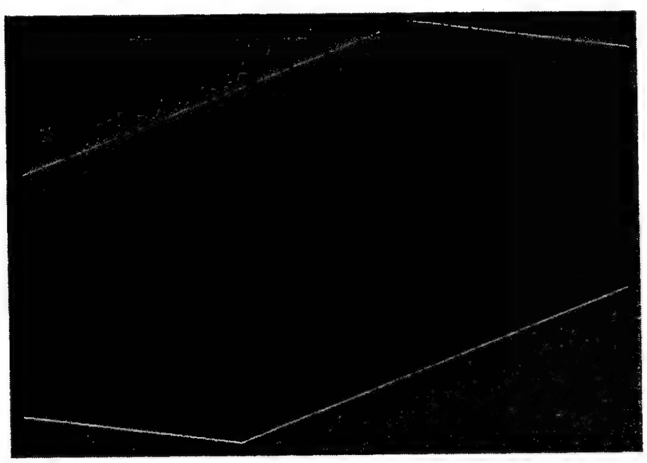


Figure 1

Current Practices

The primary intent of all inspection techniques here is to assure that the proper amount of cooling air will pass through the blade or vane during engine operation to avoid overheating and premature failure of the part, and to assure that the distribution of the cooling air is such that localized "hot spots" on the part will not be encountered. There are several primary inspection techniques presently employed. The first is light inspection. This involves inserting a small light source into the part and visually observing the presence of holes drilled through to the surface. When this is combined with a count of the holes, there is assurance that the part contains the proper number of holes and that they are open to the surface; but there is not other quantitative information available about these film cooling holes such as their size. Also, light inspections are relatively slow to perform and are greatly limited by the part configuration. In fact, many recent turbine blade and vane configurations are so complex that light inspection can only be used for certain holes on the part or not at all, either because light sources cannot be inserted or because the film cooling holes do not open to the surface along a straight line.

Another technique similar in nature to light inspection is precision pin inspection. This technique, however, is so slow and tedious that the holes can only be checked on a sampling basis. It does, however, provide some information regarding the hole diameters, to within the roundness and straightness of the hole, and can assure that the hole is open to the surface.

A third inspection technique used on all configurations is waterflow inspection. In this inspection, water is fed into the air feed holes and an inspector observes streams of water as they emerge from the film cooling holes. By so doing, the inspector can determine whether the hole is open to the surface or not. But this method does not necessarily detect partial incomplete removal of the casing core. Also, the spacing of the holes can be so close that the emerging streams quickly merge into a single sheet of water making for difficult identification of a single hole that is not flowing. A similar situation can also arise where the water streams emerge from one row of holes on the concave side of an airfoil and interfere with the water streams emerging from another row directly behind it.

A fourth inspection technique is airflow inspection. Here a specified air pressure is established across the cooling circuit. A measure is then made of the total mass of air that is flowing through the part. This may be done to the part as a whole or in several steps by sealing off certain combinations of holes and measuring the mass airflow through the remaining holes. Regardless, this technique is very labor intensive and suffers from the need for continued calibration of the equipment.

Infrared inspection performs the same functions as light, pin, waterflow, and airflow inspections and offers significant advantages over these current techniques.

The IR Inspection System

In the system used for this study (Figure 2), the refrigerant tank contained a saturated liquid/vapor mix of refrigerant R12 (dichlorodifluoromethane) at room temperature. The coolant reservoir provides a smooth delivery of coolant to the fixture, while the electronically controlled solenoid valve turns the coolant flow on and off. The flow control valve is a precision, calibrated variable orifice valve which meters coolant into the part. The part fixture is a modified production waterflow fixture which allows introduction of the coolant into the part and provides precise positioning of the part. The fixture is rigidly mounted to the lab bench and consists of two machined out aluminum blocks with precision molded urethane inserts.

A commercial scanning infrared camera with a cryogenically cooled Indium-Antimonide detector was used; it is sensitive to infrared radiation in the 3-5 micron range, has a field rate of 25 Hz, an effective spatial resolution of about 60 elements, and a thermal resolution of 0.2 degrees C. The synchronizing circuit is a special purpose electronic controller which only allows the solenoid valve to open when the infrared camera raster scan is positioned at the upper left corner of the field of view. This allows the raster scan of the camera to act as a precise clock which starts "ticking" when the solenoid opens. The camera positioning equipment consists of four calibrated manual positioners to allow three orthogonal axes of translation (x, y, and z) and one axis of rotation. The videoscan convertor consists of an analog to digital converter, a buffer memory, and a digital to analog converter. The purpose of the videoscan converter is to convert the output from the infrared camera to standard black and white televisiion video so that the data can be recorded with a videotape recorder. The infrared data is videotaped so that it can be played back a frame at a time because the thermal transient in the airfoils takes less than a second.

Advantages of Infrared Inspection

The openness of all surface cooling holes can be evaluated using infrared inspection, because no known current airfoil geometry presents significant difficulty for infrared blocked hole detection. Infrared inspection can localize the cause of abnormal total flow rates (e.g., several holes with reduced diameters) by analyzing the thermal patterns on the surface of the part corresponding to each cooling circuit, thus facilitating part rework when necessary. Also, partial blockages of internal passages in air cooled airfoils can be readily detected and localized with infrared inspection.

Infrared inspection also offers advantages of

- Improved productivity
- Improved sensitivity
- Improved accuracy
- Improved reliability (i.e., repeatability).

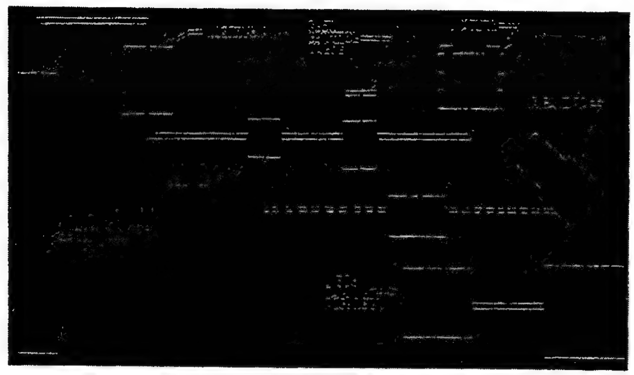


Figure 2

Recommendations

Although this study demonstrated (1) the practicality of using infrared inspection for blocked hole detection and (2) that airflow rates can be estimated using infrared inspection data, the accuracy required for acceptable airflow rate estimation has not been achieved. Improved accuracy may be obtained by making modifications in three areas: the heat transfer fluid, data acquisition, and heat transfer modeling. Refrigerant R12 was used as the

coolant in this study. The temperature of the laboratory was controlled, so the thermodynamic state (i.e., pressure and temperature) of the refrigerant was controlled as well. However, the temperature and pressure of the refrigerant were not variable in the feasibility and application studies (and cannot be controlled independently), so optimum inspection conditions could not be obtained. In addition, the pressure at the part was reduced to a suitable level by a flow control valve. This unfortunately served to reduce the sensitivity of the infrared inspection process, since the thermodynamic state of the refrigerant at the entrance to the part varied with the total flow. Finally, the possible environmental impact considerations associated with release of this material into the atmosphere pose difficult problems. Therefore, a gas (probably air) should be used as the heat transfer fluid in the future. This will allow for independent control of both the temperature and pressure of the coolant fluid at the entrance to the part so that optimum test conditions can be achieved.

In this study, specific infrared inspection variables were chosen to be measured because they were expected to be related to airflow rate. The tacit assumption was made that these variables were linearly related to airflow rate and that the unknown parameters in the linear relationships could be determined by (straight line) linear regression analysis. This is a very reasonable approach, but if a higher order parametric model of the airflow rate vs infrared measurements could be developed, then linear regression analysis could be used to determine the unknown parameters in the model and more accurate predictions over a wider range of airflow values could be expected. In addition, the number of experimental observations required to obtain a given prediction accuracy decreases as the theoretical model approaches the true physical situation.

Finally, and most importantly, theoretical analysis may well lead to inspection criteria for air cooled blades and vanes which are given in terms of infrared variables rather than in terms of airflow rates. This will greatly reduce the time required to develop an inspection procedure for new parts as they are designed.

Automated Optical Area Measurement

Turbine nozzle exit areas are currently evaluated by one or both of two totally different measurement schemes. The first, and most widely used method, utilizes a multi-probed, manually inserted mechanical gage which samples the passage dimensions at a few fixed locations. The second technique is based upon the analysis of flow and pressure relationships observed as air is forced through the nozzle passages under closely controlled conditions.

Neither of these approaches directly measures the true exit area. The mechanical gage does not factor in corner radii or irregularities on the passage perimeter, and the airflow analysis yields a calculated effective area and flow function. However, the values obtained by these techniques correlate, in varying degrees, to engine performance.

These traditional methods yield acceptable results when applied to nozzles incorporating relatively large passages and having sizeable tolerances. Repeatability/accuracy becomes marginal, however, when the passages are as small and the tolerances as tight as are encountered in the T700 Stage 1 nozzle. Airfoils incorporating a notched trailing edge design, as in the T700 Stage 1 nozzle, serve to further compound the problem.

This image analysis technique, which was a joint effort between General Electric and Bausch and Lomb Analytical Systems Division, provides a direct, noncontact measurement of the observed passage area and is amenable to computer control. Variations in passage size and shape and perimeter irregularities are automatically accommodated with no effect upon accuracy and repeatability. Repeatability, expressed as a percentage of the observed area, appears to be markedly better than that obtainable with other methods when applied to the measurement of T700 Stage 1 nozzle area.

System Concept and Operation

The feasibility model was based on the use of Bausch & Lomb's recently introduced precision Instrument Scanner Model IS-3, developed specifically for image analysis applications (Figure 3). This approach to nozzle inspection (using an IS-3 scanner, a light curtain to define the orifice, and a swinging mirror to facilitate measuring the orifice in two sections separated by a digital frame line) proved to be eminently successful. While this method does require rectification of the second (outer) section of the orifice image, the procedure—although rigorous—is not particularly time consuming.

Note: Oblique viewing of the outer section causes distortion of the image. Rectification is the mathematical adjustment of the stored data to make it representative of the true size and shape.

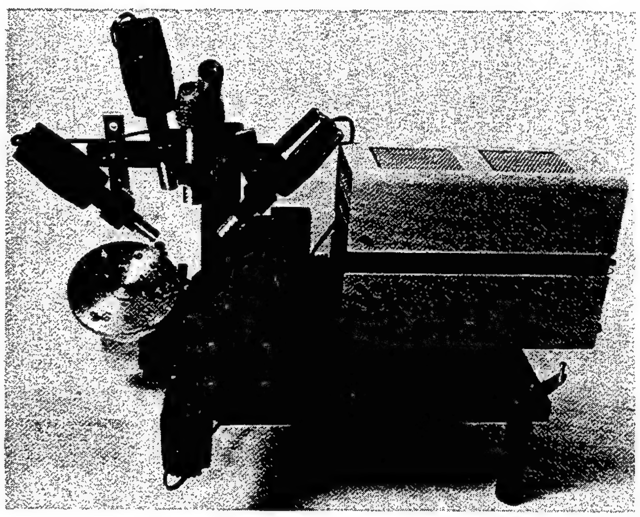


Figure 3

The measurement regime used is to average ten consecutive images of the inner half of each orifice bounded by the inner band, upper and lower airfoils and the digital frame, then switch the mirror to the other position while automatically swinging the lens back to the proper angle and position to fulfill both the focus condition and the Scheimpflug condition. Then the computer switches to a new digital frame, tangent to the previous frame on the side toward the rotor centerline; averages ten areas bounded by the digital frame, upper and lower airfoils and outer band; measures an eleventh area; computes the deviation from the average of the previous ten; rectifies the eleventh area; and corrects the rectified area to represent the average of the ten. Since rectification requires a line-by-line mapping of the image, it is too time consuming to average the rectified areas.

With the present setup, using more operator interaction than would be used in a production fixture and with none of the mechanical motions under computer control, it was possible to inspect a nozzle assembly in about 40-45 minutes. Given computer control of mirror and rotor position, which requires less operator interaction, the nozzle assembly should be measurable in less than 30 minutes, floor to floor. Further refinements in programming and/or a faster computer could lower this time by as much as 30%, if that is necessary. Some operator interaction in setting thresholds seems advisable, but does not seem to require great skill. It is probable that the operator should monitor the images to see that no gross defects slip by—it is a good opportunity to observe the orifices at an effective magnification of about 20X.

The fixture was connected to a standard Omnicom FAS-II system for automatic measurement of the nozzle images. A special software program was generated to control the acquisition of the images, the measurement routines, the rectification process, and reporting of the results.

Conclusions

Measureable improvement in repeatability is probably possible with this system, although it may incure a loss of measuring speed. For an individual passage measurement, the System 2 sigma repeatability (with 95% confidence) is ±0.24% of the observed area. This equates to ±0.0004 sq. in. for a nominal exit area of 0.1549 sq. in. Also, the total area of T700 Stage 1 nozzle, a summation of twenty-four passage measurements, can be determined with a 2 sigma repeatability (with 95% confidence) of ±0.05% of the observed area. This is ±0.0019 sq. in. for a nominally sized nozzle with a total exit area of 3.7185 sq. in.

Since this is a comparative measurement system, accuracy is dependent upon proper calibration to a known area standard. Repeatability type errors inherent in the calibration process may be reduced to an insignificant level by averaging several measurements of the standard area.

In addition, it was found that lighting is critical. Further development is needed to reduce the influence of illumination variations upon the definition of the observed area. Also, the nozzle fixturing must provide a means to rapidly adjust the viewing angle to accommodate variations in airfoil angle and to compensate for the effect of airfoil trailing edge cutback upon the positions of the exit area planes.

Experience with the manually operated demonstrater system indicates that, with minor modifications, an inspection rate of three nozzle assemblies per hour would be feasible. A fully automated system with improved computer programming should prove slightly faster. This system displays an excellent magnified image of each passage as it is measured. It also is capable of storing and comparing images. These features could prove useful for evaluating nozzle quality and symmetry.

Complexities in the processing of beam lead devices were determined that led to important guidelines relating to the fabrication of these items during a manufacturing technology program sponsored by the U.S. Army Electronics Command. Carried out by Motorola for ECOM, this program originally was designed to refine fabrication of both discrete and integrated circuit beam lead devices for large scale production.

It was also expected that—through improvements in manufacturing techniques and subsequent yields—the cost of beam lead devices could be significantly reduced and become more attractive for widespread military use. If successful in lowering costs, it was believed that commercial hybrid manufacturers would also find these devices to be more attractive. The improved reliability of beam lead devices compared with standard chip and wire devices had long been established.

Discrete Devices Offer Challenge

Soon after some of the discrete device batches had been processed, it became evident that they offered a stiff challenge to the program. Each discrete device is unique in its processing requirements—from a processing standpoint, each must be targeted for selection from what would normally be a family of devices in a normal chip and wire production line. Any variation in diffusion times, temperatures, or other processing variables on any of the devices meant that the specific type might have a low yield; similarly, some other device in the family might produce quite a high yield. Furthermore, this can occur even on the same wafer.

The same starting material and processing procedures cannot be employed in the production of beam lead devices as in chip and wire devices. Parameters change drastically when processing with beam lead technology, making it difficult if not impossible to consistently meet the device specifications. A typical cross section of a transistor serves to illustrate the continuous problems faced in processing discrete devices with beam leads (Figure 1). A top collector contact is needed instead of a standard bottom collector contact on non-beam lead devices. Probably the most critical step is in the collector diffusion. It is during this long interval that excessive diffusion of the substrate occurs, and this changes the device characteristics quite dramatically.

Motorola was not completely successful in achieving the program's goal of a 20 percent yield on any of the discrete devices. Quite possibly, some of them could and would have met or even exceeded this goal, but this would have been as much through chance as through rigid process control. Although the results were disappointing, a lesson certainly was learned—it is not practical to expect to consistently achieve high yields on a specific beam lead discrete device from a family of devices.

Greater Reliability Possible

Beam Lead Device Costs Reduced

JAMES F. KELLY is a Project Engineer at the U.S. Army Communications Research and Development Command, where he is involved with production engineering and MM&T programs. During his past five years with CORADCOM and his previous eleven years with ECOM, Mr. Kelley worked on the automation of GaAs diode fabrication, automating the optical inspection of PC boards and hybrid substrates, development of pulsed IMPATT diodes, and the online testing and adjustment of electronic assemblies in addition to many other projects. After receiving his B.S. in Electrical Engineering from Pennsylvania State University in 1953, he pursued graduate studies there and at the City College of New York. He also worked at the Army's Tobyhanna Depot in Pennsylvania until 1964.

Photograph

Unavailable

Schottky Process Implemented

The original design/process used for the production of integrated circuits employed gold doping to reduce lifetime, whereas Motorola elected to design with Schottky devices in mind. The first two yield lots failed to produce

NOTE: This manufacturing technology project that was conducted by Motorola was funded by the U.S. Army Electronics Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ECOM Point of Contact for more information is Mr. James F. Kelly, (201) 532-4958.

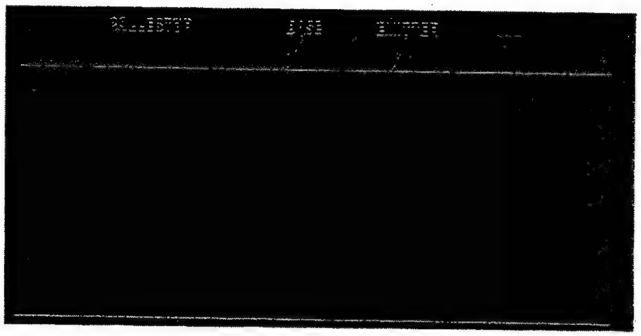


Figure 1

any viable circuits due to metallization shorts. Since the chip size had already been established, the metal line widths and spacings had to be limited to fit all of the circuitry on the chip. This resulted in the metal problems which caused the zero yields. However, this problem was corrected by the third batch.

The original design size proved to be inadquate due to the higher offset voltage of the Schottky devices. The Schottky devices are faster than conventional gold doped devices because no minority carrier injection ever occurs at the collector base junction. Therefore, no stored charge can ever accumulate in the collector region and slow down turn off time. Excess base drive is shunted away from injection and flows externally through the Schottky diode.

Master Masking Initiated

The master mask concept is a manufacturing technique that provides precision alignment, reduced device geometries, and a process relatively free from pin holes. This concept was implemented in the production of the beam lead integrated circuits in the Federal High Reliability Products Operation for the first time in this program. Essentially, the master mask is a layer of silicon nitride deposited on the initial oxide grown on the starting material. The reason for the pin hole protection should be evident—it would be necessary to have coincidence in pin holes in a precise location in both the nitride and the oxide for diffusion or metallization shorting problems to occur later.

For simplicity (Figure 2), several processing steps have been combined. First, the base and resistor diffusions have been completed, followed by the emitter diffusion. The latter is the only diffusion mask which requires critical alignment, since it is not associated with the nitride master mask. This figure represents the final step prior to metallization. A flow chart summarizes the entire operation (Figure 3).

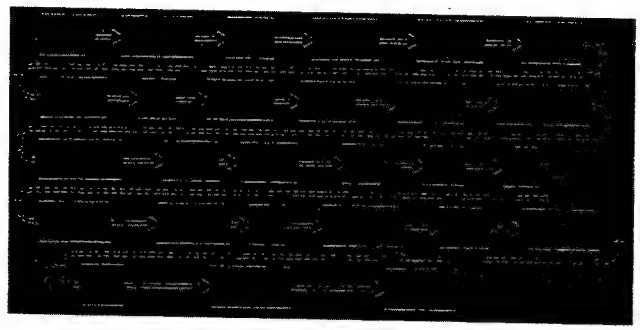


Figure 3

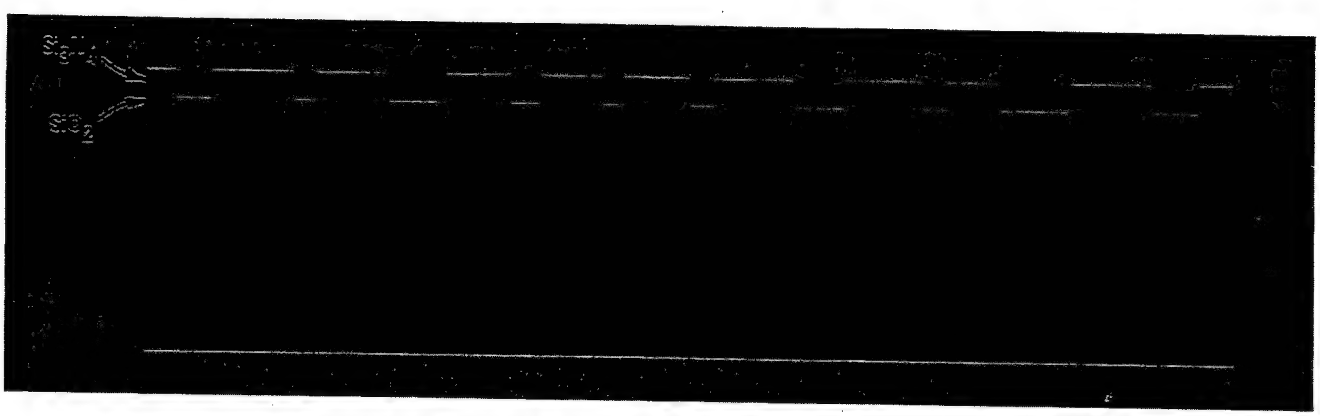


Figure 2

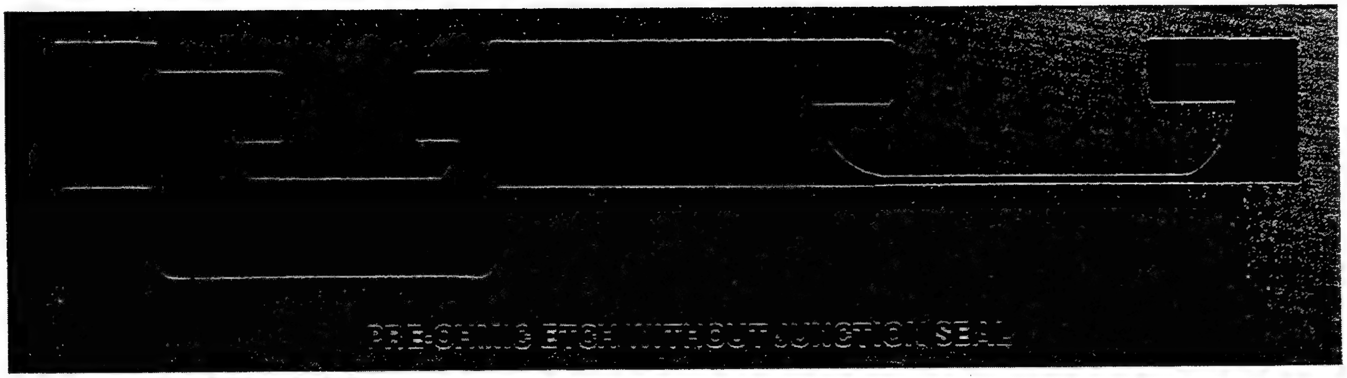


Figure 4

Modified Seal Junction Improves Yields

Another processing improvement developed earlier which improved the yields for beam lead devices was in the sealed junction. A sealed junction means that all of the PN junctions are protected from the deleterious effects of charged ions such as sodium. There is a difference in the thickness of the oxide at the point where it has been etched from the preohmic vias (Figure 4). This condition can result either in under etching, where a marginal or no preohmic metal will result, or in over etching, which can result in an undercut that can shadow the deposited metal or, in some cases, uncover PN junctions under the nitride lip.

To overcome this problem, a modified sealed junction was developed. The original master mask nitride is removed and the oxide is etched from the areas where metal contact is to be made prior to nitride deposition. Next, a thin layer of oxide is regrown in these areas; this allows subsequent etching to be uniform across the wafer, thus eliminating any voids in the platinum deposition which follows. (Figure #5 shows the results of the completed sealed junction process.)

Program Sees Early Results

Although there were some disappointments during this program, especially with the discrete devices, in the final analysis there were more positive results than negative. Specifically, processes and controls were established on the integrated circuits after only some twenty lots of material had been processed. And yields were significantly higher than first though possible.

Although significant marketing research indicated a need for these devices, the requirements for beam lead devices all but disappeared. However, much was still learned from this program, which has provided Motorola with technical experience in areas not previously attempted. Further, some of the technology advances were adopted by other production groups at Motorola, thereby enhancing their capabilities and yields.

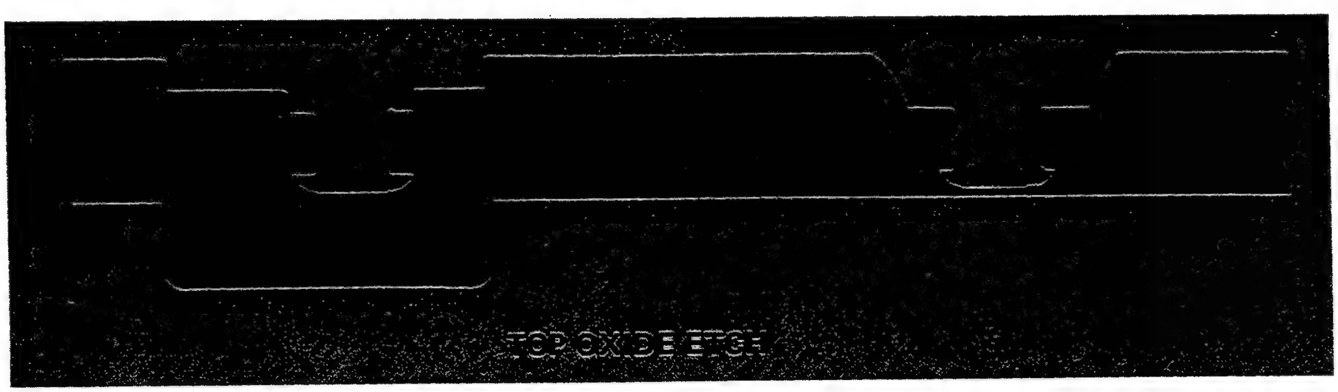


Figure 5

HERF Affords Savings

Pneumatic Mechanical High Energy Forging

JOHN JUGENHEIMER currently is Project Officer managing the design and installation of a chemically bonded sand molding system at Rock Island Arsenal. As an Industrial Engineer for the Industrial Facilities Planning Branch at the Arsenal, he also manages a program to rebuild or replace the fifty-four overhead cranes used at the facility. Prior to these tasks, he led projects on high energy forging (see accompanying article), inertial welding, fine blanking of small caliber weapon parts, and automated rotary forging of small caliber gun barrels. He has worked at Rock Island Arsenal since receiving his B.S. in Engineering Operations in 1965 and his M.B.A. in 1966.

The U.S. Army is always looking for ways of reducing the costs associated with the production of hardware items, and such was the outcome of a joint project sponsored by Rock Island Arsenal and conducted by Precision Forge Division of the Whittaker Corporation. Because forgings are heavily used in the production of such end items as combat vehicle gun mounts, artillery, small arms, and aircraft weapons, a new pneumatic/mechanical forging process—High Energy Rate Forging (HERF)—was studied to determine if it had the potential to produce such end items.

Once such potential was determined, then a contract was let to Precision Forge to purchase a Model 1220-D Dynapak HERF Machine (Figure 1). The machine and its supporting power unit and control console then were installed at Rock Island Arsenal. Subsequently, an operator was trained on the HERF equipment and a tooling engineer received instruction on the design and manufacture of HERF dies at the Dynapak plant.

A Good Process, But Limited

The following conclusions were based on work performed during this project:

(1) The HERF process is not as flexible as a steam hammer. However, for appropriate shapes and metal displacements, the HERF process will form forgings that are not possible on conventional forging equipment. On symmetrical parts with large metal displacements, the HERF process allows the forming of deep extrusions or large height to diameter ratio upsets. HER forgings can be formed in one forging blow to closer tolerances, and with little or no waste in the form of flash. Due to this and the ability to utilize smaller draft angles, HER forgings generally require less finish machining.

(2) Unsymmetrical parts, or parts where there is little metal movement, are not good HERF applications, as the die life is shortened due to high die load levels under these conditions.

(3) A standard die material such as Finkl DURO DI, Temper 2, is suitable for HERF dies which are not heavily loaded or for the body portion of the die, which is moderately heavily loaded. For HERF die punches or heavily loaded die bodies, a material with better properties is required. Heppenstall, Special C, Temper AA, was found to be quite good in heavy die loading situations.

(4) In general, HERF dies may be designed to produce forgings to closer tolerances and with less draft than conventional forgings. Draft angles used on HERF dies in this project ranged from 0 to 3

NOTE: This manufacturing technology project that was conducted by Whittaker Corporation was funded by the U.S. Army Armament Materiel Readiness Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ARRCOM Point of Contact for more information is Mr. John Jugenheimer, (309) 794-4135.

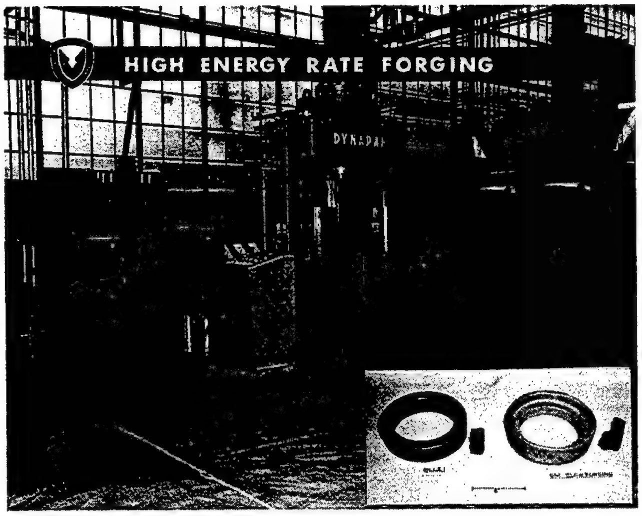


Figure 1

degrees. Conventional draft angles are about 7 degrees. Sharp corners and small radii should be avoided on HERF dies. Generous radii lower stress concentrations and will fill the forging with lower forging pressures.

(5) No metallurgical problems were observed in the production of HER forgings.

Machine Specifications

The Dynapak 1220-D HERF machine used in this study has the following specifications:

Rated Energy	225,000 foot-pounds
Rated Stroke	15 inches
Maximum Stroke	20 inches
Maximum Operating Pressure	2000 p.s.i.
Open Height	41½ inches
Die Space	24 x 22 inches
Cycles Per Minute at Rated Stroke	8
Ejector Capacity (Lower)	18 tons
Ejector Stroke (Lower)	9 inches
Ejector Capacity (Upper)	18 tons
Ejector Stroke (Upper)	6 inches
Height Above Floor	140 inches
Depth Below Floor	45 inches
Length (Left to Right)	78 inches
Width (Front to Back)	28 inches
Weight	38,700 pounds
Hydraulic Power Unit	
Main Motor	150 h.p.
Ejector Motor	20 h.p.
Filler Motor	2 h.p.
Power Requirements	220/440 volt, 3 phase, 60 cycle
Hydraulic Fluid	(Petroleum Base) 80 gals. Houghto-Safe 1120 or Cellulube 200
Height	78 inches
Length (Left to Right)	113 inches
Width (Front to Back)	52 inches
Weight	6565 pounds
Control Console	
Control Circuit	110 volt, 60 cycle
Height	50 inches
Length	24 inches
Width	23 inches
Weight	200 pounds
Total Shipping Weight	47,700 pounds

HERF Fabrication Begins

The first component selected for fabrication on the HERF equipment was a collar (Part No. 11578376, How. M185). The forging stock was a 4140 steel rolled ring 10⅜ inches OD x 7⅝ inches ID x 2¼ inches high. The stock was heated to 2000 F and forged at a fire pressure of 1975 lb. This fire pressure is near the maximum limit of the equipment. The forging was successfully formed in one forging blow which displaced (back extruded) approximately 31 cubic inches of steel.

The use of the HERF process on this component resulted in the use of less forging stock and reduced machining time for finishing. The die for this component was fabricated from Heppenstall Pyrotem, Temper A, Grade 6357 die steel. The die performed satisfactorily and remains in serviceable condition.

The second component to be forged was a recoil body (Part No. 7148066, 155MM). The forging stock was 1045 steel 4¾ inches in diameter x 2-1/16 inches high. The stock was heated to 2000 F and forged at a fire pressure of 1100 lb. The forging was successfully filled in one forging blow which back extruded approximately 18 cubic inches of steel. The forging produced is straight sided on the OD, with only three degrees draft on the ID. This configuration is not feasible on conventional drop hammer forging.

Again, the use of a HER forging resulted in using less material to produce a forging which subsequently required less finish machining.

The die material used was Heppenstall, Special C, Temper AA. This material has good toughness and heat resistance at high hardness levels. These properties were demonstrated in the forming of the above component. Although the die was subjected to high temperatures and heavy shock loadings, no die problems were experienced. The die remained in good condition and still is serviceable.

The HERF equipment also was used to fabricate a variety of nine different forgings for the Bridge Launcher M60A1. Approximately 950 forgings were produced. In an effort to reduce die costs, a less expensive die material was used for these nine dies. The die material, Finkl

Duro I, Temper 2, did not have satisfactory properties for use as the punch portion of a highly loaded die set.

One of the above mentioned parts was examined as part of the project. A land ring (Part No. C13211E3188) represented an upset type forging. The forging stock is 4340 steel 2½ inches in diameter x 3⅞ inches high. The stock was heated to 2200 F and forged at a fire pressure of 400 lb. The forging was successfully upset with one forging blow which displaced approximately 10 cubic inches of steel. The die for this component was fabricated from Finkl DURO DI, Temper 2. The die was very easy to produce because it had a shallow cavity with no ejector. In this application, the less expensive die material performed very well, and the die remained serviceable.

To evaluate the HERF technique on the forging of aluminum, the land ring die and the body die were used to forge respective parts from aluminum stock. Both components were successfully formed in one forging blow. As would be expected, the forgings were produced with lower fire pressures and less difficulty than the steel parts.

Savings in Both Tooling and Production

The collar, which was the first attempt at HERF fabrication, presently is produced using the conventional hammer forging technique. Tooling costs totaled $3750 using this technique—$1350 for the die material and $2400 for die sinking. Using the HERF process, these costs were reduced to $412 and $2000, respectively, for a total tooling cost of $2415—a net savings of $1335. Forging costs (which included stock, forging, and rough machining) were similarly reduced, from $12.20 per piece using hammer forging to $9.07 for HER forging—a savings of $3.13 per piece.

For the recoil body, which is presently machined from solid stock, the cost per piece was reduced from $18.48 to $4.27—a reduction of $14.21 per piece.

For a sample of five dies used on the Bridge Launcher forgings, a tool engineering estimate of the cost to produce the same die for a drop hammer forging was obtained. Generally, HERF dies are less expensive to produce because they require less material and are easier to machine than a drop die.

By using the HERF process, an average savings of $1365 per die set resulted.

Metallurgical Evaluation

A potential problem that is indicated in HER forging is the generation of hot tears and/or eutectic melting caused by the rapid deformation of the forging. Sample forgings of the body and the land ring forged from both steel and aluminum were evaluated to determine if there was a problem in this area.

Examination of macroetched cross sections from the five high energy forging samples did not reveal hot tears or ruptures in the hot worked surfaces. Figures 2 through 6 display the patterns of grain flow in the forged shapes for 6061 aluminum alloy and 1045 steel.

Microstructure surveys were conducted on the thick and thin sections of each forging. Eutectic melting at the grain boundaries was not observed in any of the samples.

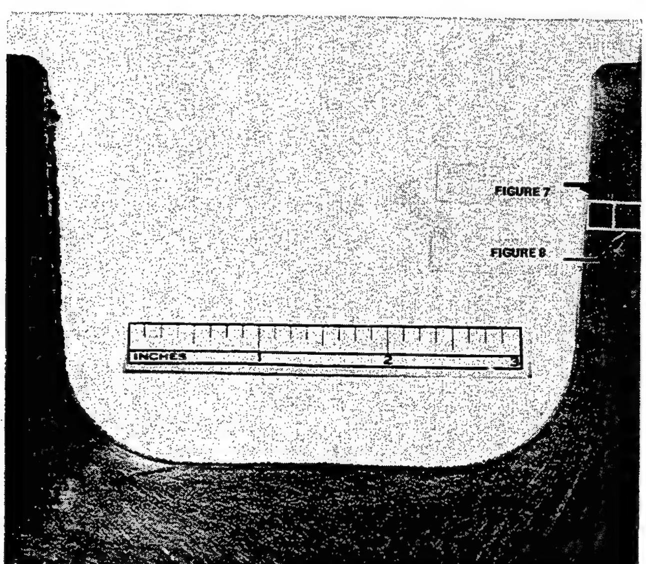


Figure 2

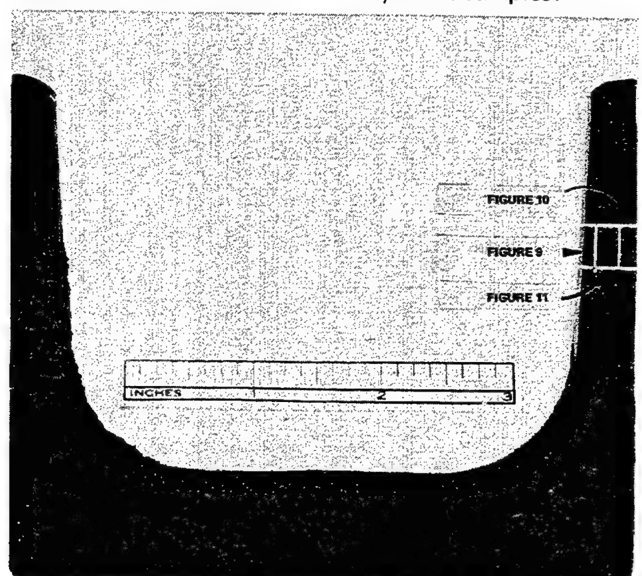


Figure 3

Figures 7 and 8 show cross sections of the ID and OD of the thin wall portion of aluminum Sample No. 1 (Figure 2

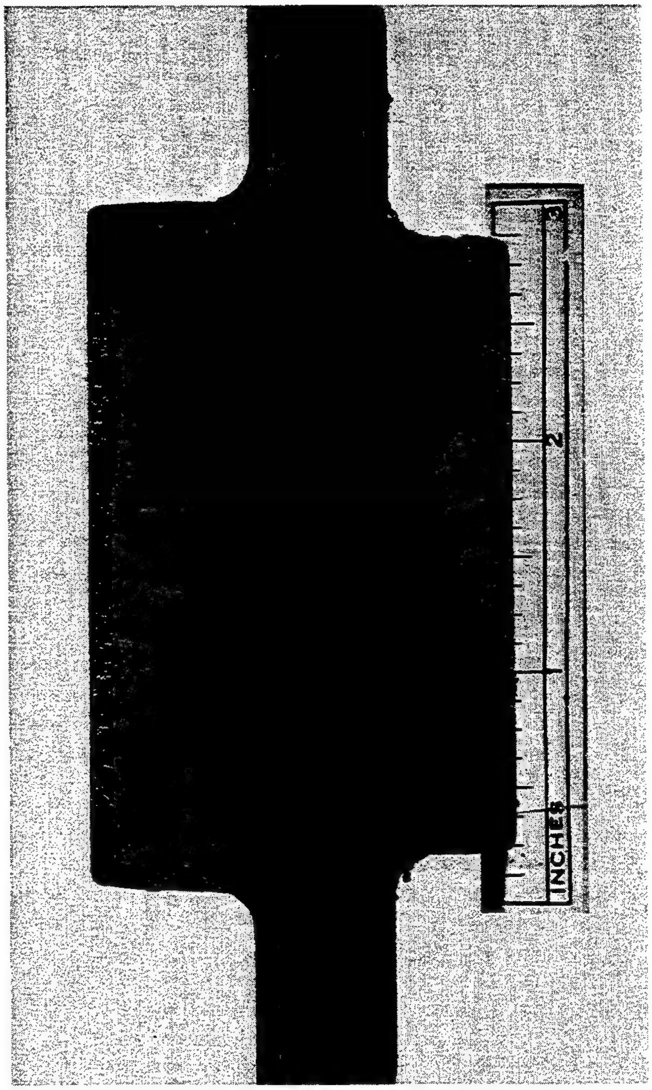


Figure 4

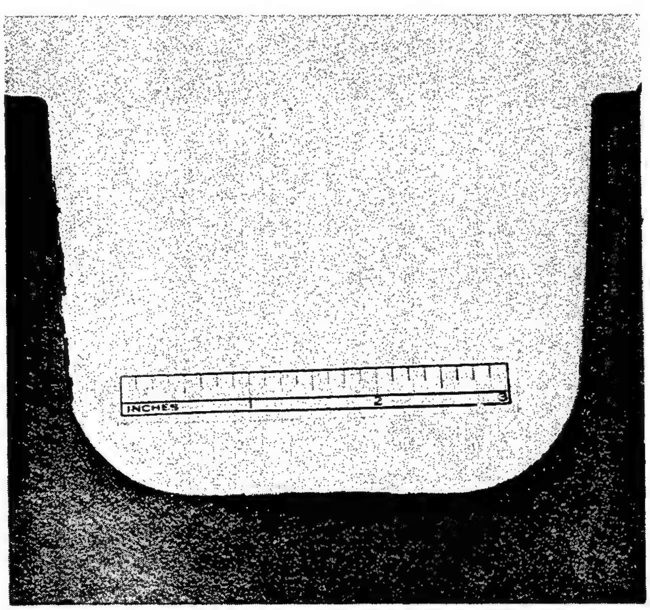


Figure 5

locates the cross sections). The large black particles prominent throughout the matrix of the thick and thin wall sections are magnesium-silicon. These particles are unusually large. When the particle size is very small, this phase is the strengthening constituent that precipitates finely after solution heat treatment and artificial aging. These extremely coarse particles, however, weaken the structure similar to overaging. Prolonged heat treatment of unforged samples at 800 F, the soaking temperature before forging, did not reproduce the coarse particle size found in Sample No. 1. Re-solution treatment in the laboratory, however, eliminated this embrittlement phase and no adverse effects are anticipated, even though the cause of the large particles was not isolated. Coarse particles were not found in aluminum Sample No. 2.

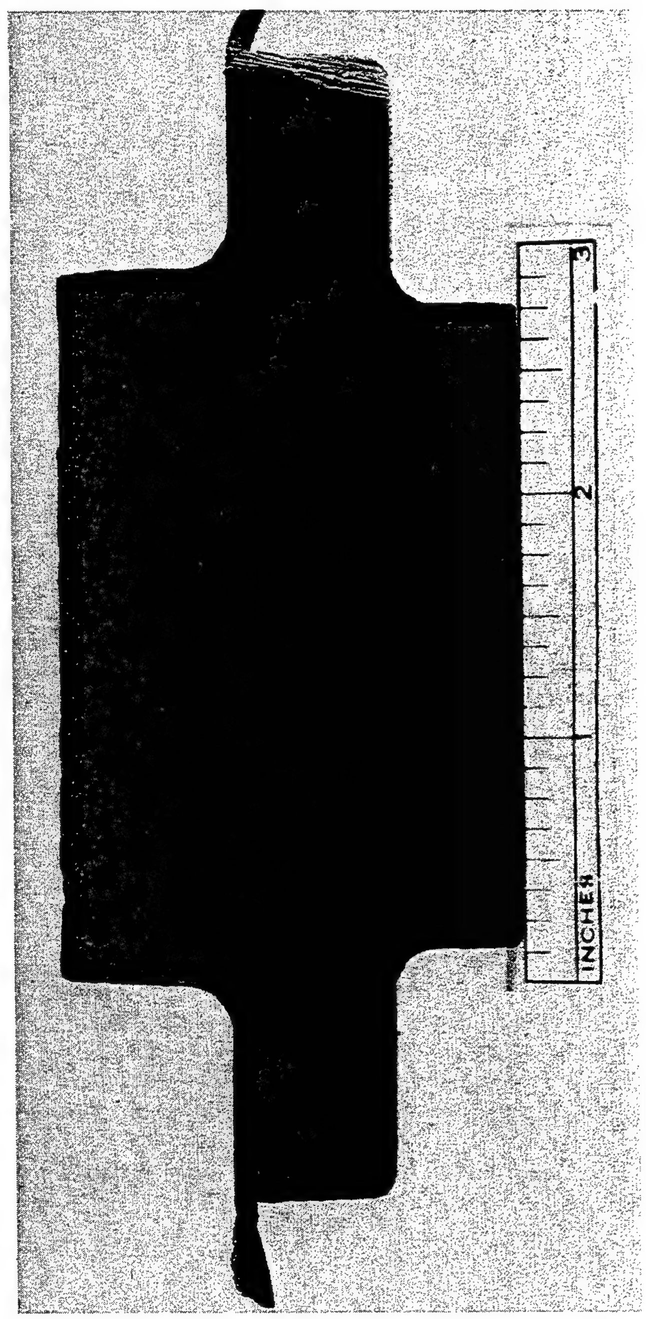


Figure 6

Sulfide inclusions appear only occasionally in the grain boundaries of the steel samples, therefore would not cause tearing at the forging temperatures. Figures 9, 10, and 11 show microsections of the 1045 steel in the thin wall, most hot worked portions of Sample No. 3 (Figure 4 locates the microsections). Decarburization appears only along the forged surfaces and is more extensive on the OD, or bottom die side. Finer grain structure also shows in the severely worked areas. Compare the grain sizes in Figure 9 and 10 with those in Figure 11, which displays the coarse, least distorted grains. The structures shown in the photomicrographs of Sample No. 3 are exemplary of the thick and thin sections in each of the steel forgings. Therefore, laboratory results indicated there was no detrimental metallurgical properties caused by HERF.

This new method of high energy rate forging will not replace conventional forging methods in every case. But in many instances it can offer lower cost and the ability to produce configurations that are not currently feasible by conventional forging methods. HERF's application will become more pronounced in the future.

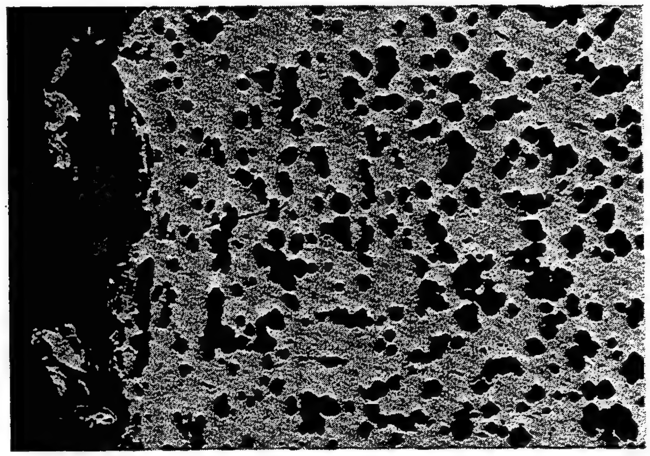


Figure 7

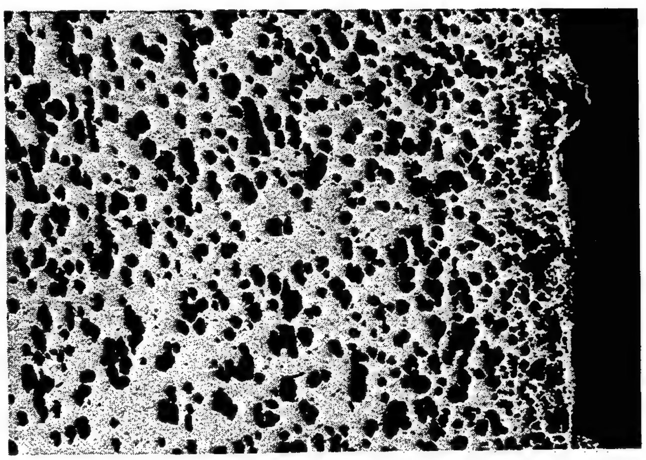


Figure 8

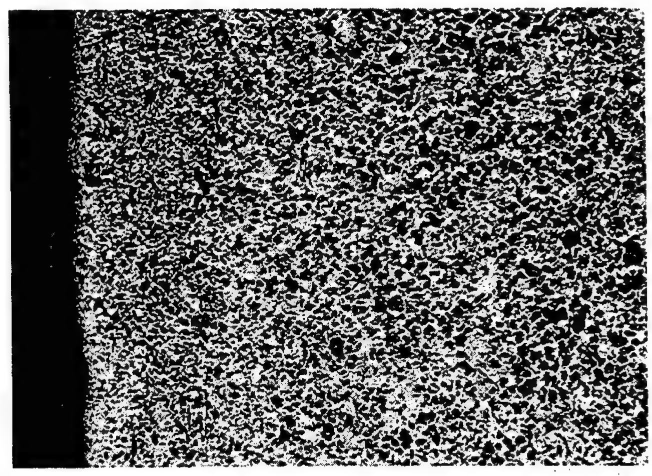


Figure 9

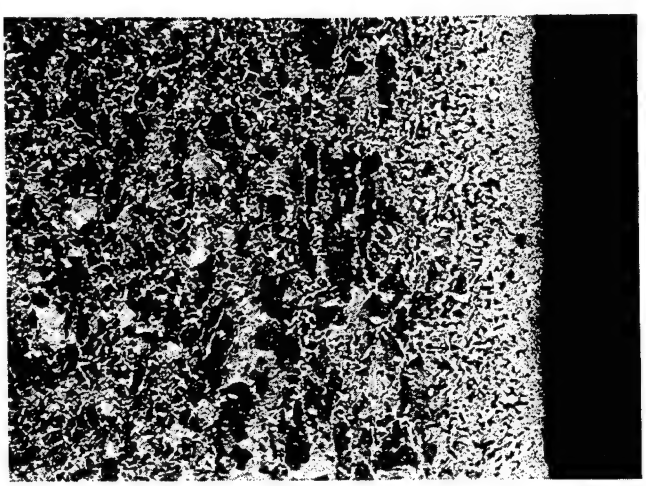


Figure 10

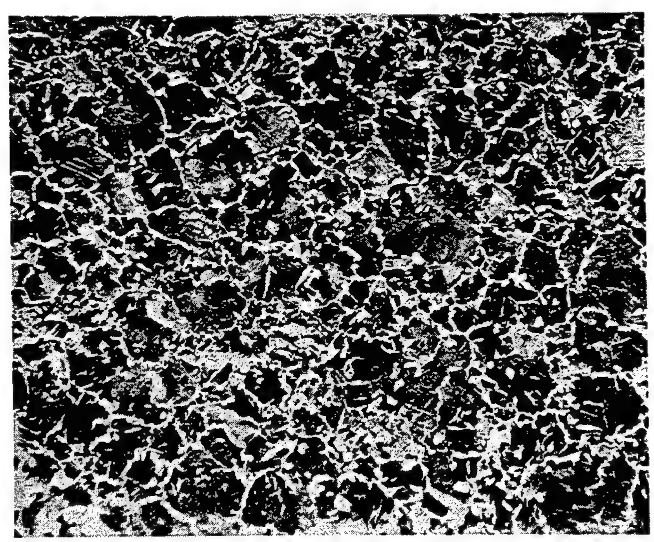


Figure 11

Compact, Rugged Telemetry Transmitter

Quantity Production Feasible

Artillery telemetry now is one whole level of efficiency higher following the development of a new compact, rugged crystal controlled L-band transmitter by the U.S. Army Materiel Readiness Command. This in-house project was undertaken to develop a telemetry transmitter that would function effectively in every current size of artillery round.

The recognized need by the U.S. Army for an improved artillery telemetry transmitter prompted development of such an item by the Harry Diamond Laboratories. A compact 1510 MHz transmitter having an efficiency of 6 percent at an output power level of 160 mW was produced. Physical dimensions are such that the transmitter can be readily potted in any artillery telemetry housing currently in use.

The Need

Information concerning the environments encountered by artillery projectiles immediately following gun launch is of prime importance to the designers of fuzes and fuze components. To acquire the signal from a telemeter early in its flight, its frequency must be maintained within a narrow passband; frequency shifts, which can be induced by shock, must therefore be minimized.

UHF transmitters are extremely sensitive to physical deformation, which can cause a small change in reactance that can—in turn—cause an appreciable change in frequency. Implementing the Department of Army directive to convert telemetry equipment from VHF to UHF required considerable in-house and contractual effort to develop ruggedized components for application in the 1435 to 1535 MHz telemetry band. One result was development at HDL of a high shock crystal and associated circuitry. A gun rugged step recovery diode (SRD) capable of high order harmonic generation was developed under an HDL contract by Hewlett-Packard Associates (HPA). Both of these components have survived tests at shock levels up to 70,000 g, a level judged sufficient for almost any artillery application.

The need remained for compact, efficient UHF circuitry that could be potted in artillery telemetry housings with the accessory hardware currently employed at VHF. The development of a prototype L-band transmitter was undertaken to fulfill this need.

F. THOMAS LISS is a Project Engineer at the U.S. Army Materiel Command's Harry Diamond Laboratories, where he has worked for the past 28 years following 5 years as a Philco Technical Representative. Earlier, he received his B.S. in Electrical Engineering from George Washington University. His primary activity currently is in the field of fuze systems. A Registered Professional Engineer in the District of Columbia, he has served as Chairman of the Instrumentation and Measurement Group of IEEE.

Photograph Unavailable

The Whole and Its Parts

The transmitter (Figures 1 and 2) contains four interconnected 1½ inch diameter modules. Components for the modulator, crysal oscillator, and 75 MHz power amplifier were mounted on a single 1½ inch diameter printed circuit board. The multiplier, filter, and 1.5 GHz amplifier sections were assembled on three separate boards. Stripline circuitry was employed to confine the field of the region between ground planes and thereby reduce the detuning effects caused by subsequent encapsulation. Input and output impedances were kept at 50 ohms to facilitate electrical testing of the individual modules and to allow the transmitter to be assembled with minimum redesign.

In the schematic diagram (Figure 3) transistors Q1, Q2, and Q3 are the modulator, crystal oscillator, and power amplifier stages, respectively. The quartz crystal, which is located in the center of the board, was developed by HDL to withstand gun launched accelerations up to 70,000 g.

NOTE: This manufacturing technology project that was conducted by Harry Diamond Laboratories was funded by the U.S. Army Materiel Readiness Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The HDL Point of Contact for more information is Mr. Tom Liss, (202) 394-2410.

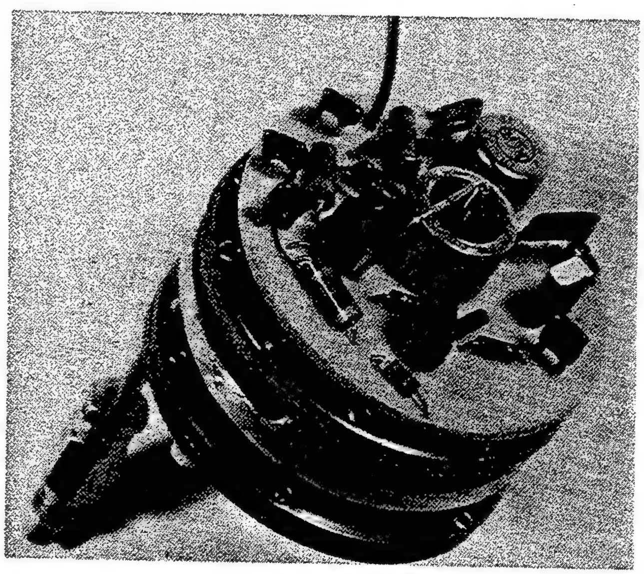


Figure 1

Modified Colpitts Oscillator

The crystal oscillator is a modified Colpitts type utilizing a 2N2553 transistor in a common base configuration. Temperature tests over a -40 to 90 C range indicate that a frequency stability of 0.002 percent can be obtained with oscillators of this type.

In telemetry applications, the transmitter is modulated by a subcarrier oscillator (SCO) whose frequency is modulated by transducer data. The SCO output is applied to transistor Q1 and appears across capacitor C3, which also serves as an RF ground for the base of the crystal oscillator. Measurements of the resulting spectrum at 1.5 GHz showed a phase modulation sensitivity of 13.1 radians/volt.

In phase modulation, the frequency deviation is directly proportional to the modulating frequency, so higher SCO output voltages are required at lower subcarrier frequencies. With a 70 kHz subcarrier, a r.m.s. output voltage of 136 mV is required to obtain a deviation of ±125 kHz. Using a 165 kHz subcarrier, the same deviation can be obtained with a 58 mV output.

Step Recovery Diode Multiplier Used

Since it was desirable to minimize the number of tuned circuits and tuning adjustments to facilitate the encapsulation procedure, a single step recovery diode (SRD) was employed to provide a frequency multiplication of twenty. A detailed analysis of the input impedance of an SRD multiplier was performed by Hewlett-Packard Associates under an HDL contract. This analysis showed that the input impedance of a network consisting of the drive inductance L and SRD can be represented by a parallel equivalent impedance containing an inductive reactance in parallel with a resistance. Here, a capacitor resonates with the equivalent inductive component of the input impedance at the input frequency and provides a low impedance path for most of the spectral components of the diode generated pulse. The equivalent resistive component is then matched to the 50 ohm source impedance by means of a matching network. A choke provides RF isolation for the self bias resistor, while another coupling capacitor provides dc isolation from the source.

Unlike a conventional diode, the conduction angle of an SRD is very large since charge stored in the diode during the forward current portion of the cycle maintains the diode in the conducting state over a major portion of the

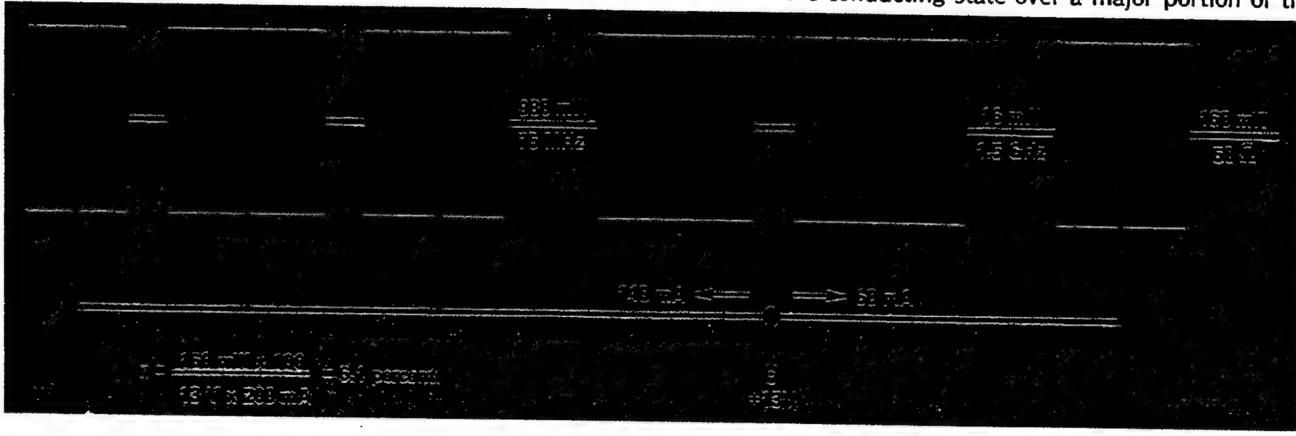


Figure 2

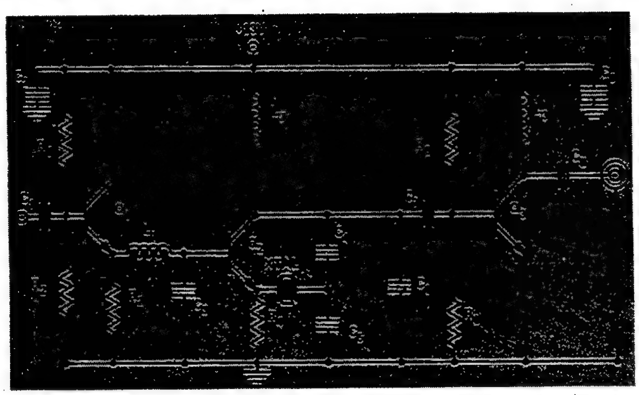


Figure 3

reverse current cycle. Near the end of the reverse current cycle, the stored charge is depleted and at this instant, the diode becomes an uncharged capacitor. Energy stored in the field of the drive inductance L is then transferred to the capacitor, and the exchange of energy that follows would produce the typical ringing waveform of an RLC circuit if the diode remained in its off state. Since the second half cycle of the transient drives the diode into conduction, the resonant action is destroyed, and a single pulse having a width approximately equal to one half the period of the output frequency is produced once each input cycle.

The diode generated pulse enters the output line, where it undergoes multiple reflections from the output and diode ends of the line. Reflections at the output end occur without phase reversal, while those at the diode or shorted end occur with phase reversal. Since the pulse traverses a distance of one half a wavelength between output reflections and returns each time with its phase reversed, a damped waveform appears at the output.

The output capacitor was experimentally adjusted while the line length was appropriately foreshortened until the maximum amplitude in the damped output spectrum appeared at the 20th harmonic of the input frequency. In this state the damped waveform could be filtered to obtain a CW output with little loss due to rejected sideband energy.

Interdigital Filter

Undesired harmonics of the 75 MHz fundamental are attenuated at the multiplier output by a five element interdigital filter having a center frequency of 1.5 GHz, a fractional bandwidth of 5 percent, and a temperature coefficient of 185 kHz/degree C. With this form factor, the amplitude of the closest 75 MHz harmonic was 45 dB below the 1.5 GHz carrier.

The measured filter insertion loss was 5 dB as predicted from L-band measurements of the dissipation factor of the dielectric employed in the stripline. A similar estimate from manufacturer's data indicated that the insertion loss can be reduced to 2 dB by employing 50 mil alumina substrates.

One Stage L-Band Amplifier

The 1.5 GHz output from the filter is amplified to a level of 160 mW in a one stage amplifier employing a 2N5715 transistor. Values for the components of the input and output matching networks were experimentally determined. The collector is connected to the dc supply through the center conductor of the eyelet feedthrough capacitor, which also provides an ac ground for the inductor. Input bias is supplied through a quarter wavelength line terminated by a feedthrough capacitor.

Future Plans Uncertain

Future plans called for a continuation of the development effort in the areas of temperature compensation and g-hardening. The crystal oscillator provided adequate frequency stability over the -40 to +60 C temperature range, but additional compensation will be required to maintain the transmitter power output level constant. Also, it should be possible to stabilize the amplifier stages by replacing the fixed bias resistors with appropriate temperature compensating resistors. The filter has adequate bandwidth and needs no compensation.

With the exception of the low loss capacitors and the 2N5715 transistor, all circuit components were qualified for an artillery environment. Prototype printed circuit boards were not qualified, since it was intended to fabricate the final version on ceramic substrates. It was also planned that the entire unit would be tested at shock levels up to 40,000 g following current shock tests on the capacitors and the 2N5715 transistor.

Individual boards subsequently were fabricated and tested up to 40,000 g, and a complete unit was assembled. However, attempts to initiate pilot production at commercial facilities failed. Because the requirements to fabricate these units in mass at HDL do not exist, further in-house work has been postponed.

JOHN RODD is a Project Leader in the Advanced Engineering Section at the Benet Weapons Laboratory of Watervliet Arsenal. He has worked at this facility of the U.S. Army Armament Research and Development Command since the early 1960's following several years' work in General Electric research labs. At Watervliet, Mr. Rodd has developed expertise in machinability, contributing to the industrial base manufacturing effort related to cannon in the specific areas of trepanning, abrasive machining, and ceramic tooling. He has achieved recognition for his expertise in these fields by the American Ordnance Association and the Tooling and Manufacturing Engineering Society. A graduate of government industrial training centers, he has published articles in his field in the majority of the major industrial magazines.

Photograph

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THOMAS M. WRIGHT is the Coordinator of ARRADCOM's ManTech activities at Watervliet Arsenal, where he serves as Chairman of the Technical Working Group for MM&T Planning. He also is a member of the CAD/CAM Subcommittee of the DoD/Industry Manufacturing Technology Advisory Group and serves on DARCOM's CAM Steering Group. Prior to joining the staff at Watervliet six years ago, Mr. Wright operated his own construction business. He has a B.S. in Research Methods from New York University at Albany, where he will receive his M.S. in Management in May, 1983.

Photograph

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Study Shows Designers Not Aware

Selective Surface Finish Cuts Costs

Deliberate, thoughtful analysis of real machining and finishing needs in the production of gun components can save on costs and time, according to a manufacturing technology study recently completed in-house by the U.S. Army Armament Materiel Readiness Command at its Watervliet Arsenal facility. Over design and over specification of surface finish requirements by only a small increment can dramatically increase the total cost of a manufactured component.

A source of manufacturing difficulty often arises during original product design because many designers are not familiar with general overall machining cost factors. For example, specifying a 16 finish instead of a 63 finish increases the component finishing cost by as much as 300 percent. The economics involved in general manufacturing are the result of part specifications; these specifications usually are based on "best engineering judgment" rather than on any cost analysis or relationship of required surface finish to final product cost.

The products manufactured by Watervliet Arsenal range from massive cannon tubes that weigh in excess of 12,000 pounds to smaller items which weigh less than one pound. Some of the items, although considered to be minor components, are extremely complex and therefore difficult to produce. This situation is further complicated by dimensional tolerance and surface finish requirements. Therefore, tolerance and surface finish specifications for both major and minor components are a source of manufacturing difficulty.

As an example, a final product tolerance of ±0.002 will cause in-process dimensions to be controlled much more closely during the manufacturing cycle to insure that the final requirements are met. Locating or holding fixtures, tooling, gages, and the general step by step manufacturing process must also be controlled and continuously monitored to meet final tolerance and surface finish specifications. This can cause an item to become extremely difficult to produce and therefore more costly.

NOTE: This manufacturing technology project that was conducted by Watervliet Arsenal was funded by the U.S. Army Armament Materiel Readiness Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The Watervliet Point of Contact for more information is Mr. Thomas M. Wright, (518) 166-4231.

Slide Chart Attempted

Because surface finish and part tolerances are the primary factors in dictating final product manufacturing techniques and overall costs, a product survey was undertaken to determine the most advantageous areas to study. Results indicated that the most benefit would result from a combined study of major items such as gun tubes, breech blocks, and breech rings. Engineering drawings, manufacturing routings, and machining techniques were then reviewed to establish areas of principal concentration.

Once the product survey to isolate those areas which have the widest payback ratio was completed, statistical test data was compiled for computer analysis. A slide chart or ready reference chart which depicts machining characteristics then could be produced from the data.

A Solution to the Problem

The review of the statistical test data, however, indicated a new approach. Currently, a reference pamphlet is used to discuss tolerances in general. But it would be much more beneficial to have reference charts that depict the ratio of machining costs versus specified surface finish. This guide would be extremely valuable to design engineers, planners, and shop personnel.

Figure 1 shows the variety of finishes that can be achieved by various manufacturing techniques. For example, to obtain a 4 finish, many separate tools may be involved such as lathes, milling machines, grinders, super finishers, and other highly specialized pieces of capital equipment. The closer the tolerance, the slower the operation. The skilled craftsman must use extreme caution in approaching the final tolerance of ±.001″, whereas sawing to a tolerance of ±.125″ can be accomplished quite simply and usually without difficulty.

Figure 1

Figure 2 was developed as a result of several tool life tests. This chart was constructed to show the vast increases in machining cost for various surface finishes specified. And, as discussed before, product surface finishes in many instances are arbitrarily dictated. There are situations that demand surface finishes be machined to the 32 finish requirement; however, many of these 32 finish requirements actually are machined somewhere between a 16 and 32 finish. By referring to Figure 2, it readily can be established that to produce a surface finish beyond what is specified will result in an enormous increase in product cost. Therefore, if a finish specification serves no practical purpose, the tolerance should be relaxed until it falls in a category of being economically justifiable.

Figure 2

Testing Upholds Need for Charts' Standards

A series of surveys were conducted on the gun tube, breech block, and breech ring of the 105mm M68 gun to see if design specifications were really practical and needed as established.

The survey of the breech block showed that most component tolerances and surface finishes were fully justified and required no modification or clarification.

After a careful review and analysis of all statistical test data, it was determined that the 32 finish requirement for the gun tube could not be maintained by alternate methods of machining—i.e, turning tools alone. In all tests, tool wear could not be controlled and resulted in either an out of tolerance condition for the area machined or an unacceptable surface finish. The present method of grinding was the only acceptable method of producing the specified requirement. On the other hand, many nonfunctioning surfaces such as the bore evacuator zone, the taper zone, and the muzzle end area require only minimal surface quality. Specifying close tolerances and a high degree of surface finish for these areas would result in unnecessary machining time.

Information Useful

It was concluded that surface finish and tolerances do not appear to present any serious burden to the manufacturing process of the breech ring. However, locating dimensions are being held to a much closer tolerance because they are necessary to establish future fixture positioning.

The survey of the component parts of the 105mm M68 gun only tends to confirm that, if surface tolerance and finishing requirements are to be kept most cost efficient and practical, then there is a real need for the information contained in the two charts presented here.

JOHN HONEYCUTT is a Project Engineer for the U.S. Army Missile Command. His areas of experience at MICOM include three years of mechanical engineering work, four years of aerospace engineering in materials and structures, and fifteen years of work in materials engineering. A member of the Alabama Society for Professional Engineers, Mr. Honeycutt holds patents on a Stress Corrosion Measurement Apparatus and an Igniter Wire Insulator Assembly. He received his B.S. in Mechanical Engineering from Mississippi State University in 1960.

Photograph

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Thermomechanics Improve Product

Internal Shear Forging for Missiles

Internal shear forging experiments conducted by IIT Research Institute for the U.S. Army Missile Command have successfully established procedures for producing missile primary structures as monolithic construction with integral ribs. Using shear forging tooling in conjunction with an engine lathe, this MM&T program developed guidelines for large volume production of these structures and showed the cost savings resulting from implementation of the internal shear forging processes.

The major conclusions from this program are that

- Internal shear forging can be implemented to produce missile primary structures to near net shape.
- The cost savings accompanying implementation of this process are substantial.
- Although the strengthening effect of thermomechanical treatment (TMT) seems to be minimal for 2014 aluminum on the basis of tensile data, further testing for fatigue, fracture, and stress corrosion resistance is necessary before the effects of (TMT) can be confirmed.
- Dimensional stability and residual stresses resulting from TMT must be fully characterized.

Before this cost effective, near net shape technology is implemented, however, it is recommended that the thermomechanical aspects of the process be carefully reviewed and evaluated in terms of the following:

- Tradeoff between higher property levels (if existent) and increased processing cost due to multiplicity of steps
- Influence of process variables on the reproductivity of end properties and product appearance
- Magnitude, polarity, and distribution of residual stresses resulting from TMT and their effect on the dimensions and mechanical properties of shear forged subshells.

NOTE: This manufacturing technology project that was conducted by IIT Research Institute was funded by the U.S. Army Missile Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The MICOM Point of Contact for more information is Mr. John Honeycutt, (205) 876-1074.

Cost Reductions Prime Goal

Missile primary structures currently are fabricated from 2014 aluminum alloy sheet and plate stock by welding together the cylindrical outer skin of the structure and a series of internal stiffening rings. Cost reductions were sought for large production quantities by implementing internal shear forging to produce these structures in monolithic construction. An additional benefit is the possibility of enhancing structural performance by incorporating thermomechanical treatments (TMT) into the internal shear forging process for these structures.

Internal shear forging consists of deforming a cylindrical ring between a rotating external die and an internal roller, resulting in a thin walled tube with integral internal ribs. It is fairly well established as a production process for axisymmetric components and is known by a variety of names including internal tube spinning and internal roll extrusion.

The objective of this program was to establish the internal shear forging process for missile primary structures featuring thermomechanical treatment. For aluminum alloys, TMT typically involves introducing cold work into the precipitation hardening cycle, which results in many cases in improved tensile properties, fatigue strength, fracture toughness, and stress corrosion resistance.

The work performed on this program included tooling design and fabrication, an exploratory study of basic parameters, internal shear forging experiments, processing of deliverable parts with thermomechanical treatment, tensile property determination, and an economic analysis involving considerations of production requirements and costs for internal shear forging.

Work Leads to Important Conclusions

The principal aim of the rolling experiments task was to study the deformation processing characteristics of aluminum alloy 2014, to establish the starting condition of the alloy, and to predict its response to deformation during internal shear forging.

In shear forging, the material is subjected to a reduction in thickness in an incremental fashion similar to the rolling process. Furthermore, because the current method of manufacture for these missile structures utilizes rolled stock, it was decided to study the rolling characteristics of this alloy and to establish, if possible, the desired processing parameters for internal shear forging. Both material related variables and processing variables were considered. The material related variables included

- Alloy temper
- Size and thickness of the workpiece
- Starting, intermediate, and final microstructures
- Presence and distribution of secondary phases.

The process related variables involved selection of parameters like reduction per mass, rolling temperature, lubricant, rolling speed, number of rolling passes, heat treatment between passes, and post-rolling heat treatment. In selecting the range of these variables, due consideration was given to the interrelationships between temperature, reduction, and strain rate, as these variables directly influence the reduction behavior and final properties of the rolled material. Initial roll temperature, temperature and thickness of the starting workpiece, and the heat generated during plastic deformation also influence the final properties and microstructure of the rolled product.

Alloy 2014 is a heat treatable age hardening alloy that contains Al with Cu, Mg, and Si as the main alloying elements. Addition of Si enhances the response to artificial aging (T6 temper), with the final strength being higher than for the naturally aged (T4) condition. This alloy is widely used in structural applications. For deformation processing, it is desirable that the alloy be in a fully annealed (0 temper) condition. The fully annealed temper yields stabilized precipitate phases in a matrix which has high ductility and can undergo a considerable amount of plastic deformation.

Compromise Necessary

For this work, 2014 alloy could not be procured in the fully annealed condition. Therefore, a 1 inch thick rolled plate was procured in the T651 temper (solution treated, stretched 0.5-3%, and then artificially aged). A 150 x 150 x 25 mm (6 x 6 x 1 in.) plate of the 2014 T651 plate was then annealed at 413 C (775 F) for 2 hours to achieve the annealed condition (0 temper) before processing.

Microstructures were examined by optical microscopy as well as scanning electron microscopy (SEM). Energy dispersive X-ray (EDX) analysis was employed for all identification of various constituent phases. All microscopy specimens were etched with Keller's reagent. Tensile strength values quoted here were obtained from the longitudinal (parallel to rolling) direction unless specified otherwise.

The rolling experiments led to the following conclusions:

(1) It is essential that the starting condition of the 2014 alloy for bulk deformation processing be in a completely annealed condition in order to achieve maximum ductility of the matrix with stabilized precipitates. In the present study, this condition was not achieved to the desired extent, perhaps because of the T651 temper of the starting material.

(2) The present experiments indicate that at higher temperatures deformation rates (from changing the rolling speed) do not produce a pronounced change in the appearance of the grain structure. Shear forging of the proposed part may involve localized differences in deformation rates, but the present results indicate that this should not pose any serious problem.

(3) Post-rolling heat treatment experiments demonstrate that the utmost care must be exercised during solution treatment in order to achieve the desired strength and ductility in the final product. Grain boundary melting can be avoided if the solution treatment is preceded by a homogenizing anneal at a lower temperature. Precise temperature control is, however, extremely important.

Tooling Design and Fabrication

A heavy duty engine lathe (LeBlond Model 2516) was converted into an experimental shear forging machine. Some of the important aspects of tooling design for internal shear forging—based on the metalworking requirements imposed on the tooling components—were roller design, die construction, and surface finish (Figure 1).

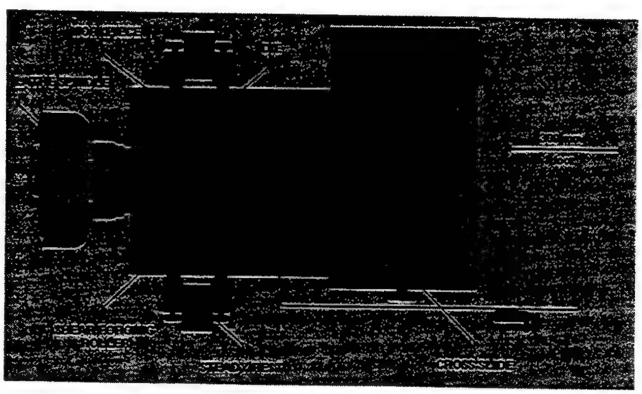

Figure 15

To minimize deflections and enable the lathe to perform capably under the high forces generated during shear forging, the loading and support members of the tooling were "boot strapped" together (Figure 2). The loading path thus generated would go from the roller arm directly to the interconnected support arm, with load transfer to the lathe possible only in the event of gross misalignment.

Application to Subshells

Using the modified tooling, thick walled 2014 O-rings were successfully shear forged into thin walled internally ribbed tubes. Thermomechanical treatments were evaluated by introducing cold work at various stages of the precipitation hardening cycle for the workpiece material. Lubrication during the initial passes—which were made at about 177 C—was accomplished using a graphite spray on the workpiece. Solution treatment was done in a Globar heated electric furnace at 55 C. The final passes following solution treatment and different preaging treatments were made at room temperature (to prevent overaging) using a light oil for lubrication.

Metal Flow

Various types of metal flow were encountered in internal shear forging. A near uniform flow of metal under the roller with no folding of metal ahead of the roller typically occurred after the first two or three passes, with gradual heating and increased plasticity of the workpiece enabling higher percent reductions to be taken. In the initial passes, the metal flow was usually less uniform because of loading limitations and insufficient percent reduction in the wall. An extensive case of nonuniform flow included intense shearing of the surface layers of metal, with formation of dead metal zones, folds, and laminations. In contrast, the rib forging operation that was performed to orthogonalize the rib section produced uniform flow of metal under the roller despite some shaving of the vertical face of the rib due to friction. Numerous structure defects were observed in the early trials which had to be studied and resolved.

In addition to 2014 Al (program alloy), a few tests were conducted with 2024 workpieces fabricated from plate by roll bending and welding. In contrast, all the 2014 Al workpieces were ring rolled to provide a weld free structure. The as formed skin showed decreasing strength with increasing wall reduction. This is not the expected result of softening during mechanical working, since the preform was fully annealed to begin with and the processing was conducted below the recrystallization temperature. However, it may be an evidence of the Bauschinger effect, since the tensile tests reversed the polarity of the stress field present during forming.

The strength levels after heat treatment to the T6 condition showed no significant effect of deformation behavior, the yield and tensile strengths being in accordance with handbook data for these materials.

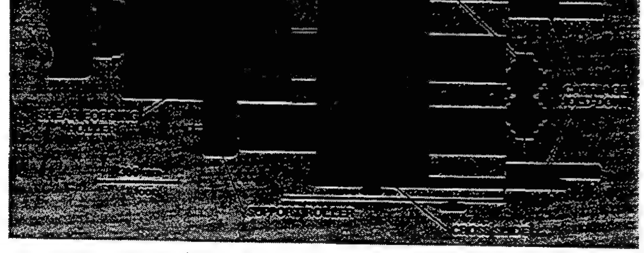

Figure 2

Thermomechanical Treatment

Thermomechanical treatment (TMT) is a means of improving the properties of certain alloys by introducing plastic deformation into the heat treatment cycle. The microstructural changes accompanying the process are different from those in conventional processing. Depending on the alloy and the nature of the TMT, this can result in improved tensile strength and elongation, better fatigue, creep, and wear resistance, and higher levels of fracture toughness and stress corrosion resistance.

Six different TMT cycles were evaluated; they differed from one another primarily in the stage of the precipitation hardening sequence in which cold work was introduced. In addition, the time and temperature of preaging (after solution treatment, before cold work) was varied wherever possible to investigate the precipitation kinetics to a limited extent. In all cases, the starting material was a ring rolled and fully annealed ring of 2014 aluminum. In general, cold work following solution treatment is seen to fragment the grains, with the most dramatic fragmentation occurring when cold work is imposed on a fully aged T6 structure.

Response Marginal

On the basis of the tensile properties measured, a double aging TMT cycle was selected for production of the deliverable subshells. Two other cycles were selected for preparation of samples for further testing by MICOM.

In general, cold work appears to hasten the precipitation hardening kinetics of 2014 aluminum. The final aging temperature thus has to be lower than for conventional artificial aging to the T6 condition to avoid overaging.

The tensile test data indicates that the response of 2014 aluminum to thermomechanical treatment is only marginal insofar as tensile properties are concerned. Although higher strengths have been attained here than in conventional T6 heat treatment, it has been at the expense of ductility (tensile elongation). The effect on fatigue strength, fracture toughness, and stress corrosion cracking would be evaluated by MICOM, if warranted, external to this program.

Deliverable Subshells

Three deliverable subshells were processed. This involved shear forging (170 C), rib forging (170 C), solutionizing and quenching, artificial preaging at 170 C for 1 hr, shear forging (cold) by 10 percent, final artificial aging at 150 C for 10 hr, and trimming to size. In addition, the skins of an additional subshell section were processed by T6 and T9 treatments and delivered to MICOM for metallurgical and mechanical testing.

It was observed that internal shear forging with TMT—with the final passes performed cold on a preaged structure—resulted in considerable residual stresses. These stresses were either nonexistent or not apparent when shear forging annealed parts at warm temperatures.

The target component was intended to be internally shear forged, leaving the central region as a single thick rib. Grooving the thick rib in a lathe setup then would generate two separate thin ribs. However, in producing the deliverable subshells, it was not possible to machine the rib to the desired specifications: the shear forging die was designed as a split (two piece) construction held together by tangential bolts to facilitate part removal after forming. Under load, the two piece assembly was progressively distorted (and the bolts stretched), resulting in an oval die and, hence, subshells with approximately 1.6 mm (1/16 in.) ovality.

It was decided not to machine the ribs so as to avoid the risk of breaking through the skin and rendering the subshells unusable.

Later experiments showed that a split die is not necessary and that by reverse feeding the roller, the part can be forcibly extracted from the die. A strong, rigid, single piece die thus could be used to eliminate ovality and rib machining problems.

Production Requirements and Costs

The capital equipment for internal shear forging consists primarily of one or more heat treating furnaces and one or more heavy duty engine lathes or (preferably) spinning lathes. The quantity of each of these items would be determined by the cycle time and the rate of production desired. Tooling for internal shear forging would be modified as necessary to suit the particular spinning machine used. Additional items include a lubricant spray system, an oxyacetylene heating system (optional), and material handling equipment.

An annual requirement of 2000 parts calls for one spinning lathe ($200,000) and three heat treating furnaces ($300,000) for solutionizing, preaging, and final aging. The total investment in implementing the new technology in place of the current process is estimated to be $1,000,000. The annual return on this investment is expected to be $6.86 per dollar invested for a payback period of 1.7 months.

The shear forging die, rollers, support members, and other items of tooling are expected to cost $100,000, including rework and replacement parts for one year's production. Amortization over 2000 parts will result in a tooling add-on cost of $50 per part.

The labor requirement for internal shear forging of 2014 aluminum subshells with thermomechanical treatment has been estimated at 12 standard hours per part, whereas the current process of fabricating the subshell as a welded structure was estimated to consume 130 standard hours per part. The production costs derived from these figures show that shear forged subshells would cost about one-eighth that of comparable fabricated structure

Attractive Process Holds Promise

Ferrite Phase Shifters From Arc Plasma

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Work at the Electronics Technology and Devices Laboratory of the U.S. Army Electronics Command has demonstrated that a low loss lithium ferrite phase shifter can be economically fabricated with the arc plasma spray (APS) process. Also, it can be expected that lower microwave losses can be achieved by arc plasma spraying than by the more conventional processes.

An attractive feature of the arc plasma process is that it can readily adjust to changes of phase shifter design and frequency range with a minimum of expense. This feature proves the arc plasma process to be economical for the fabrication of a much smaller number of phase shifters than other processes.

Original Work With Nickel Zinc

The primary objective was to establish an economical ferrite powder suitable for the arc plasma fabrication of C-band and S-band nonreciprocal ferrite phase shifters. The original effort to arc plasma spray ferrites was with nickel zinc ferrite powders. These powders were prepared by flame spray, fluid bed, and spray dry processes. APS techniques were developed for spraying thick deposits greater than 20 mil at deposit rates in excess of 50 mil/min/sq in. Also, a microwave magnesium maganese ferrite was deposited with good hysteresis properties and low dielectric loss tangent. These results indicated the feasibility of arc plasma spraying a microwave quality ferrite around a dielectric, thus forming the basic ferrite phase shifter configuration.

Arc Plasma Deposition Economical

A ferrite phase shifter is a long ferrite toroid with a dielectric inserted in the center (Figure 1). The length and cross sectional dimensions will vary with different applications and frequencies of operation; however, the fabrication technique remains relatively the same. The current technique used in fabricating this phase shifter requires a ferrite toroid with close dimensional tolerances, machining, and the insertion of a dielectric into the toroid. Some designs require the drawing of cement into the ferrite-dielectric interface to insure that no air voids exist. The assembly of the ferrite and dielectric adds significantly to the cost of the phase shifter and can affect device per-

NOTE: This manufacturing technology project that was conducted by the Army's Electronics Technology and Devices Laboratory was funded by the U.S. Army Electronics Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ECOM Point of Contact for more information is Mr. Richard W. Babbitt, (201) 544-2284.

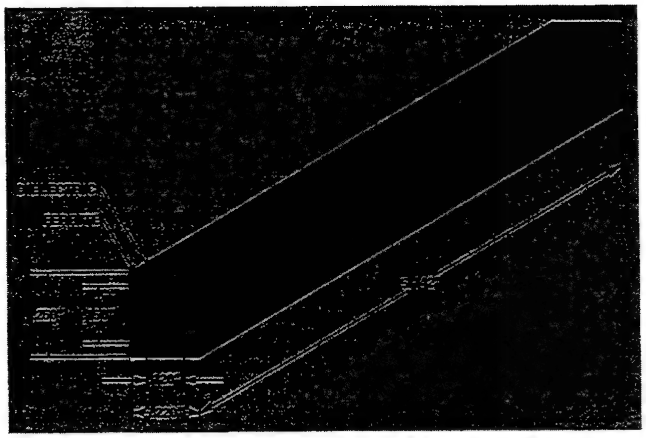

Figure 1

formance. The arc plasma deposition of a ferrite around a dielectric presents a more economical process for fabricating phase shifters, since an intimate ferrite/dielectric bond can be achieved with the arc plasma process.

Arc Plasma Gun Used to Melt and Project Powder

An arc plasma gun is used to melt a ferrite powder and project it onto a target (Figure 2). The heat produced by the arc plasma is dependent upon the arc current and arc gas. However, the heat to which the powder is subjected depends on the point of the plasma stream into which the powder is fed.

The powder can be fed internally into the arc gun, or externally at some place in front of the arc gun (Figure 3). The internal feed is the more efficient for melting the powder; however, volatile elements can be lost, oxides are more readily reduced, and "loading" may occur. Loading occurs when the powder melts before leaving the gun (anode), where it resolidifies and builds up, interfering with the plasma stream and resulting in pieces of the ferrite breaking off and depositing on the target. An external feed eliminates the possibility of loading, but more heat is required to melt the powder, causing greater difficulty in feeding all the powder particles into a uniform heat zone of the plasma.

A compromise of these two powder feeds is to use a cover which is not as susceptible to loading as the internal feed, yet restricts the powder to a narrow temperature zone. Regardless of the technique, it is necessary that the powder be fed with velocity capable of penetrating the plasma stream, thereby producing a sufficient melt. The velocity of the powder is controlled by the powder carrier gas flow rate and the size of the powder port. After the powder is in the plasma stream, the degree of melt it will experience is dependent upon the heat available and the time in the plasma (dwell time). Dwell time is controlled by the arc gas flow rate, the temperature to which it is heated, and the size of the nozzle (anode). Smaller nozzle ports are considered high velocity nozzles. The three variables which determine the plasma velocity are

- The arc gas flow rate
- The temperature to which the arc gas is heated
- The nozzle size.

After the feed powder has been melted, the arc plasma deposits it on a target. A good deposit results when the powder reaches the target in a molten state. The conditions which contribute to the powder striking the target in a molten state are

- The distance from the gun to the target (spray distance)
- The speed at which the powder travels
- The ambient temperature from the gun to the target.

The more complete the melt and the greater the impact of the target, the denser the deposit and the stronger the bond. The bond which can be achieved with the arc plasma process is the feature which makes this process attractive for the fabrication of phase shifters. However, for the arc plasma process to be economical, it must deposit ferrite powders at fast rates around a dielectric and with the required magnetic properties.

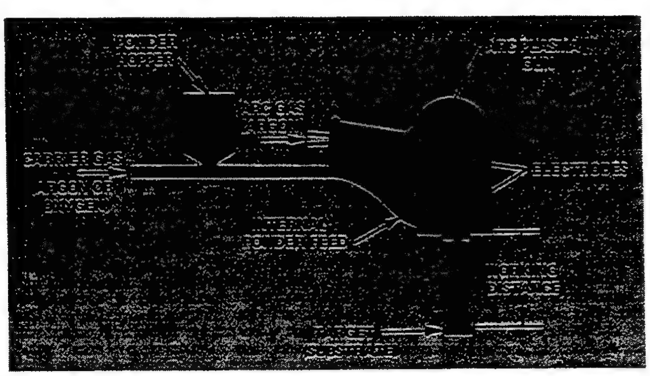

Figure 2

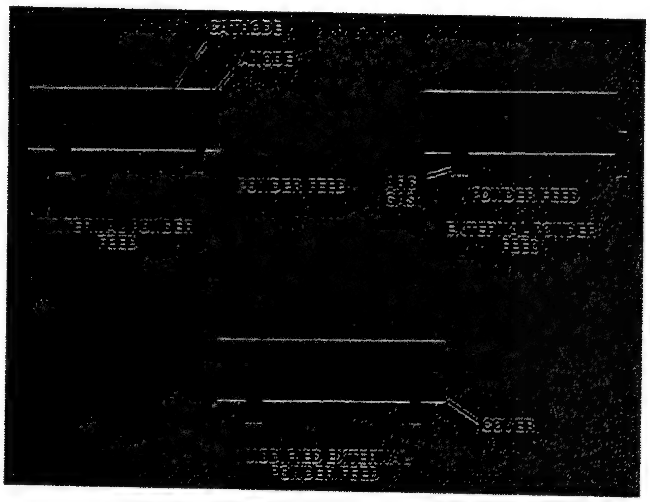

Figure 3

Best APS Parameters Found

A powder for arc plasma spraying bulk ferrite bodies must be free flowing to obtain a uniform and high deposition rate. Two other powder characteristics which influence the spray process are the particle size and size distribution. It has been established that particle size influences the deposit density. High density deposits were achieved with lower spray parameters (arc current) for small particle sizes. A powder with a large size distribution has a greater tendency to load, since the arc plasma parameters are normally set to melt the mean particle size. This causes the smaller particles to melt before clearing the arc gun, while the larger particles are not sufficiently melted to produce a dense deposit.

Compositions of lithium ferrite and yttrium iron garnet were selected for the arc plasma fabrication of C- and S-band phase shifters. Lithium ferrite was the primary composition since it is less expensive than garnets and, with proper substitutions, it can be tailored for several microwave frequency bands. Ampex's Ferrite Materials Division was chosen as the supplier of ferrite powders used in this program.

Deposit Efficiency (Dep. Eff.) is the percentage of powder sprayed which is deposited around the dielectric. The Dep. Eff. is very important to the economics of the arc plasma fabrication of phase shifters. Not only does it directly affect the deposition rate, it also affects the amount of powder required to spray a phase shifter. A high Dep. Eff. requires that the ferrite powder be sufficiently melted to adhere to the dielectric and that the powder hit the dielectric. Thus, not only is the aim of the plasma gun important, but also the cross section of the dielectric in relation to the spray span. Dielectric inserts of most phase shifters are relatively small targets for the arc plasma spray and much of the powder misses the dielectric. The Dep. Eff. for the S-band phase shifter is approximately 40 percent compared with 25 percent for the smaller C-band dielectric which is sprayed with a cover to limit the spray span. Improved cover designs should produce a narrower spray span, increasing Dep. Eff. and deposition rate.

The deposition rate for phase shifter fabrication is defined as the thickness of ferrite deposited in one minute around a one linear inch length of dielectric (mil/min/in). The deposition rate is dependent on the Dep. Eff. and the amount of powder fed to the plasma gun. Even with the relatively low Dep. Eff., deposit rates as high as 80 mil/min/in. can be achieved. Normally, 12 grams of powder per minute is fed through the arc plasma gun to produce a deposite rate of 50 mil/min/in.

Arc Plasma Spray Parameters

The determination of how the arc plasma parameters affect the magnetic properties was done with stress free samples. Stress free samples are obtained by separating the deposited ferrite from the dielectric before annealing. In this manner the anneal relieves any stresses resulting from a coefficient of expansion mismatch between ferrite and dielectric. Two arc plasma guns were evaluated—one with an internal powder feed and one with an external powder feed. It was possible to achieve low microwave losses and good hysteresis properties with either gun. However, different spray conditions were required for each gun in order to achieve satisfactory material properties. The significant difference is that the internal feed gun had to be operated with much higher plasma velocities, no helium, and at a greater spray distance. The internal feed generally produced samples with higher densities but was susceptible to loading and had a more limited range of acceptable spray parameters compared with the external feed gun. The external feed gun, modified with a cover, was selected for the bulk of this effort.

Dielectrics for APS Phase Shifters

A program to develop dielectrics for inserts for the APS fabricated lithium and yttrium iron garnet phase shifters was initiated by the Ceramic Group of the U.S. Army Electronics Technology and Devices Laboratory. The dielectric requirements were

- Low microwave loss
- High dielectric constant (K)
- A similar thermal coefficient of linear expansion as the ferrite to be deposited

Fabrication Technique

Using established spray parameters with an appropriate anneal cycle, it is possible to arc plasma spray lithium ferrite with suitable microwave properties around a dielectric which has a close matching coefficient of expansion. The arc plasma fabrication process is done by spraying ferrite on a rotating dielectric. This spraying process is done in an oven (Figure 4), which is preheated to decrease thermal shock and enhance ferrite deposition. While the dielectric is rotating, it is pulled past the stationary arc plasma gun once until the desired length is coated. The rate of pull and the ferrite deposition rate determine the deposit thickness. The ferrite is oversprayed from 20 to 50 mil, and then the outer dimensions are machined to tolerance.

Utilizing this fabrication technique, no expensive tooling is required for design changes of the phase shifter or for spraying phase shifters for different frequency bands. When two differently designed C-band phase shifters were sprayed in sequence, the only requirement was that a different size dielectric be used and the rate of pull adjusted for the change in ferrite wall thickness.

The Future

Based on spray times, it can be expected that for higher frequency devices the arc plasma process will be even more attractive when compared with any current or experimental technology. It is also expected that, as more advanced arc plasma spray techniques are developed, improved and lower cost phase shifters will be realized. One

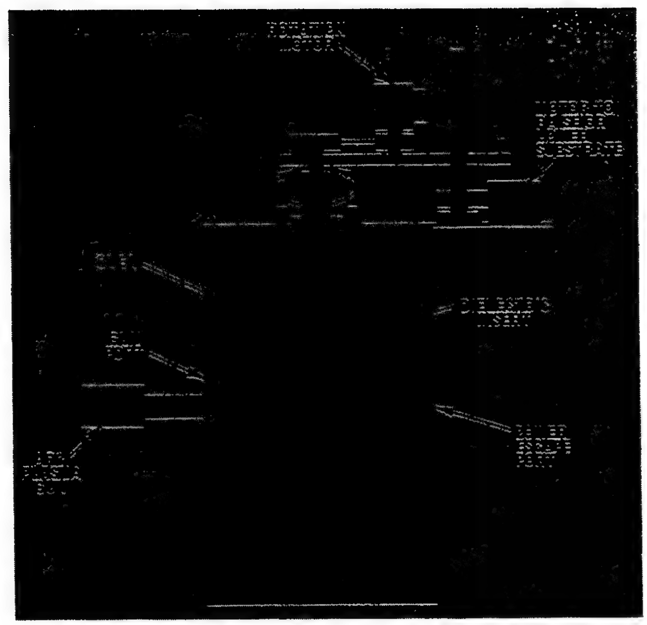

Figure 4

such improvement will occur when spraying is done with the drive wires in place. This will not only reduce cost by eliminating two dielectric halves, but it is also expected to reduce the need for mode suppressors, since the ferrite phase shifter will be one solid composite from dielectric to waveguide, without any air voids.

It is important to remember the significant fact that this arc plasma spraying effort was done with powder designed for conventional sintering processes. It can be expected that improved devices will be achieved with ferrite powders specifically developed for the APS. It has already been established that fully reacted powders are desirable for the APS process. In addition, it has recently been found that a powder with a narrow size distribution improves the reproducibility of the APS process. Neither of these two characteristics—i.e., fully reacted powders with narrow size range—are generally desirable for conventional sintering processes. Finally, the newer arc plasma guns with higher power and higher velocity should also contribute to improved materials and devices from the arc plasma process.

Technique Modifications Required

Plasma Spray for Millimeter Wave Shifters

NOTE: Mr. Richard W. Babbitt, author of the article on ferrite phase shifters on page 31, also is the author of this article. His biographical sketch can be seen on page 31.

Arc plasma spraying (APS) techniques for fabricating phasors for millimeter frequencies from 35 to 95 GHz have been developed successfully in a manufacturing technology project completed by the Army's Electronics Technology & Devices Laboratory for the U.S. Army Electronics Command. These new techniques will reduce the cost of producing these devices up to 75%, according to conservative cost projections.

Arc plasma spray techniques previously were developed for fabricating low microwave frequency nonreciprocal ferrite phase shifters (3 to 6 GHz). The purpose of this phase of the work was to demonstrate the feasibility of the APS process for fabricating low cost, high performance, nonreciprocal millimeter wave ferrite phase shifters. The ferrite phasor (Figure 1) for operating at 35 GHz has a dielectric thickness which was varied between 9 and 18 mils and a ferrite wall thickness which was varied between 15 and 22 mils. This design produces maximum differential phase shift and minimum insertion loss per unit length for a ferrite composition.

As previously noted, when conventional fabrication techniques are used to produce millimeter ferrite phasors, they are difficult to reproduce, are expensive, and generally provide inadequate performance characteristics. Conventional techniques require material processing, tooling, and machining whereby numerous time consuming steps are required to meet stringent dimensional tolerances in order to minimize air voids at the ferrite-dielectric interface. The small size and tight tolerance of the ferrite toroid and dielectric insert are responsible for the high cost of millimeter phasors, and unavoidable air gaps at the ferrite-dielectric interface produce inadequate device performance.

The APS process has been successfully used to fabricate lower frequency 3 to 6 GHz phasors. During the low frequency effort, it was recognized that the greatest economic impact of the APS process would be realized for higher frequency phasors. The APS deposition of a ferrite around a dielectric is a simpler and more economical pro-

NOTE: This manufacturing technology project that was conducted by the Army's Electronics Technology and Devices Laboratory was funded by the U.S. Army Electronics Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ECOM Point of Contact for more information is Mr. Richard W. Babbitt, (201) 544-2284.

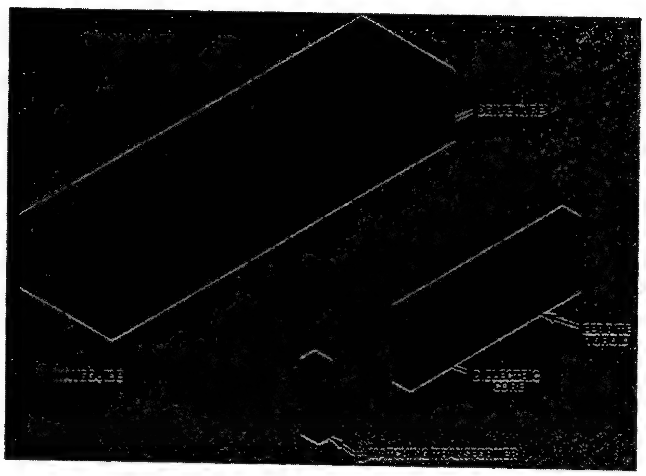

Figure 1

cess for producing phasors than the current conventional fabrication procedure. Also, the process produces a bonded ferrite-dielectric interface which enhances device performance. The tolerance of the center of the ferrite toroid is exactly the dimension of the dielectric insert, while the outer dimensions of the ferrite are readily machined to within ±0.001 inch. After machining, the APS phasor is annealed to reduce microwave losses and coercive force prior to device testing.

Fabrication

A lithium ferrite powder was selected for spraying millimeter phasors, since a lithium ferrite composition can be tailored to have a high saturation magnetization to 5000 G with a square hysteresis loop and can be annealed at relatively low temperatures. The arc plasma spray equipment and procedure used to spray millimeter phasors was the same as that used for the lower frequency C and S band phasors. However, the thin dielectric of millimeter phasors necessitated a modification of the arc plasma spray parameters and a new technique for placing a drive wire.

Because thin dielectrics are very susceptible to warping during spray procedure, the APS parameters were modified. They included spray distance, arc current, and plasma velocity (arc gas); spray distance was increased, while arc current and arc gas were decreased. The low arc gas decreases the plasma velocity, which increases the dwell time, thus compensating for the lower arc current. The spray distance was the most critical parameter, with variations of 0.25 inch having a significant bearing on warpage. However, it was desirable to have the spray distance as short as possible, since this parameter also has a significant effect on the ferrite deposition rate.

The large dielectrics used for C and S band phasors were sprayed as two slotted halves joined together, forming a center hole for a drive wire. The dielectric used for millimeter phasors is too thin for this technique to be practical. The technique selected was to form a hole for the drive wire during the fabrication of the phasor. An inexpensive and simple procedure was developed which required bonding a thin piece of boron nitride to the dielectric. The boron nitride maintained its size and shape during spraying but was completely burnt out during the anneal cycle, leaving a hole for inserting a drive wire. Using this technique made it possible to determine hysteresis properties when the hole was large enough for two wires. However, due to the thin ferrite wall (less than 0.022 in.), stresses from a coefficient of expansion mismatch and machining stresses are more critical than experienced for the C and S band phasors.

Device Performance

The first phasors tested were those fabricated from the 1200 G lithium ferrite. The 1200 G composition has a rela-

tively high dielectric constant—17, thus it is not possible to achieve an ideal match to the quarterwave boron nitride transformer, especially with the high K lithium titanate dielectric. This accounts for the relatively narrow bandwidth achieved for these phasors. Bandwidth is also restricted by spurious modes generated when the phasor is heavily dielectrically loaded. The greater phase shift with the higher K dielectric is due to the greater concentration of RF energy in the phasor.

Evaluation of APS phasors fabricated with a 4100 G lithium ferrite was initiated after the evaluation of several of the 1200 G APS phasors had been completed. The phasor from this initial small batch of 4100 G powder had maximum remanent magnetization of 1800 G. A computer program based on an 1800 G remanent magnetization and a dielectric insert with a K of 26 predicted a theoretical differential phase shift of 336 degrees per inch. The APS phasors produced 300 degrees per inch differential phase shift, which is approximately 90 percent of theoretical. (See Figure 2.)

Although the conventional phasor possesses a higher remanent magnetization than that of the APS toroid, the APS phasor produces more than twice the differential phase shift. This is due to the fact that the APS phasor is loaded with a higher K dielectric and lacks air gaps at the ferrite-dielectric interface. It can be projected that, as the 4100 G lithium ferrite powder is modified for the APS process, remanences approaching 3000 G will be realized. A remanence of this magnitude will produce 500 degrees per inch differential phase shift.

Projected Costs Tell the Story

Currently, it takes less than 2 minutes to spray a 1 inch phasor. Based on the APS operating costs, the spraying costs are less than $4 per phasor. Using the $4 per phasor spraying cost and including the dielectric cost, $5 is the cost projection for arc plasma spraying a 35 GHz phasor. The machining cost for the APS 35 GHz phasor is estimated to be less than $10. This cost figure is based on our machining experience and a current $18 cost for machining an APS C band phasor, which requires significantly more machining. Allowing $5 for profit and an 80 percent yield, a 35 GHz APS phasor will cost less than $25. This estimate assumes no significant improvement in the APS technology; and more important, it should be realistic for small quantities—i.e., one hundred or more phasors. This estimated cost—$25 for an arc plasma fabricated 35 GHz phasor—can be compared to a current price in the range of $100 for a conventional ferrite toroid. However, there still are significant costs associated with inserting the dielectric, also a questionable yield.

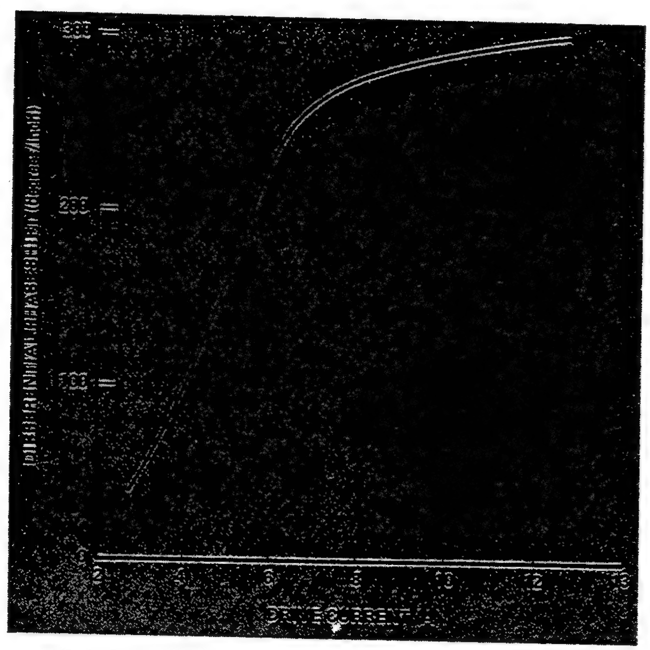

Figure 2

Brief Status Reports

Project 4310. DMSO Recrystallization of HMX/RDX. The current method of recrystallizing HMX/RDX is inefficient and uneconomical. It requires large amounts of raw materials (especially cyclohexanone or acetone), process vessels, and manpower. A solvent with much greater soluating power is required. DMSO is such a solvent and can be used for processing large amounts of HMX/RDX. This project is developing a pilot scale process for recrystallizing HMX/RDX using DMSO. Continuous operation of the DMSO pilot line was successfully demonstrated. Design rate was achieved with some equipment problems. Preliminary qualification testing of pilot plant recrystallized material was initiated. Finished explosives made from DMSO recrystallized RDX/HMX were shipped to Lone Star and Louisiana AAP for end item testing. At LSAAP, M112 demonstration charges were loaded with composition C-4. About 53 of the 72 scheduled interim qualification tests were completed. No adverse effects due to DMSO recrystallized explosives was noted. Long term storage tests were conducted; M55 detonators and grenades were fired successfully. For additional information, contact R. Goldstein, ARRADCOM, (201) 328-4122, or D. Yee, MPBMA, (201) 328-2243.

Project 4311. Develop Automated Production Equipment for XM 692. The present production facility to LAP the XM692 mine dispensing system is limited to a manual/manual assist operation with attendant production unit costs and high personnel exposure. This project will provide equipment designs and prototype equipment to automatically load and assemble the XM37 mine, thereby reducing personnel hazards and production costs while providing a more uniform and reliable item. The plug puller passed acceptance testing and is in production at LOAAP. Two machines are in production and two are 90% debugged. For additional information, contact L. Weiner, ARRADCOM, (201) 328-5538, or M. Condit, MPBMA, (201) 328-2712.

Project 4466. Evaluation of TNT, Cyclotol, Octol in Melt/Pour Facility. The melt/pour explosive fill equipment was designed for the Army's preferred fill, Composition B, with little regard for the application of this equipment to the alternate explosive fills. This project will develop melt/pour utilization plans for the processing of TNT, Cyclotol, and Octol. The K-Tron Weighfeeder was selected to feed TNT to the mixer. Cost growth of $239K was approved to assure a complete evaluation of the TNT solids mixer with live explosives. Installation drawings, preliminary survey of the instrumentation and control system, and fabrication of the S. Howes mixer were completed. The controlled cooling equipment has been installed. For additional information, contact L. Manassy, ARRADCOM, (201) 328-3890, or B. Waldman, MPBMA, (201) 328-4071.

Project 4469. Automatic Insertion of Grenade Layers. The manual insertion of grenade layers into projectiles is a highly manual, costly, and hazardous operation. This project will develop automated equipment to perform the insertion of grenade layers into the M483-155mm Projectile. Final design drawings for the grenade insertion system were completed. Fabrication and assembly work was completed and the machine was successfully demonstrated. For additional information, contact L. Weiner, ARRADCOM, (201) 328-5538, or M. Condit, MPBMA, (201) 328-2712.

Project 4480. High Speed Head Turn Tool Modification for SC Ammunition Production. The SCAMP case submodule has continuously experienced excessively high usage rate of head turn tool modules. This is due more to the tool module going out of adjustment than to breakage of tooling. This project will evaluate two designs to improve the head turn tooling. The first design uses a self opening hollow mill to replace the cutter and roller guide presently used. The second design includes new methods of holding the piece for head turning. For additional information, contact M. Leng, ARRADCOM, (201) 328-5688, or S. Ward, MPBMA, (201) 328-2712.

Project 4484. Improved Hi-Speed Waterproofing Application for SC Ammunition. The primer lacquer and mouth waterproofing applicator systems on the SCAMP primer insert submodule periodically fail to perform as required. The misapplication results in expensive rework. The current primer system will be replaced with a precision pumping system. The mouth waterproofing system will employ a two part probe for increased efficiency. A less labor intensive reservoir filling method will be investigated. For additional information, contact M. Leng, ARRAD—COM, (201) 328-5688, or S. Ward, MPBMA, (201) 328-2712.

Project 4498. Consolidation and Automatic Assembly of Small Mines. Offline operations and multiple handling are required for the predominately manual LAP operations. This project will provide the process procedures for consolidating within the mine housing, also concepts for automation of the assembly operations and a final report. Designs were approved for an automated lens tester and auto-

mated soldering machine. The contractor is proceeding with fabrication of equipment based on these designs. For additional information, contact J. Bracilgliano, ARRADCOM, (201) 328-5569, or M. Condit, MPBMA, (201) 328-2712.

Project 4503. New Process for SAW Tracer Ammunition. There is no U.S. capability for manufacturing the proposed NATO 5.56 Tracer Bullet in the quantities required for the SAW system. The conventional small caliber tracer bullet manufacturing equipment will be modified to produce the Nato Tracer Bullet. For additional information, contact S. Kaszupski, ARRADCOM, (201) 328-4687, or B. Hajduczok, MPBMA, (201) 328-2742.

Project 4335. Alternative Process for Titanium Gyroscope Components—Copperhead. Contemplated production methods are costly and remain essentially unchanged from those used to produce components for the engineering development version. This project will apply and prove out a more cost effective production technique specified for the manufacture of each gyro component. Test specimens were forged and hot isostatic pressed using different titanium compositions. Preforms were designed, compression properties and preform sintering process determined, and sample HIP studies performed. Four of five gyro parts have been successfully fabricated using selected powder metal processes. Tensile tests of both commercially pure Ti and Ti-Ga-4V Ti alloy have been performed to verify properties. For additional information, contact R. Pellen, ARRADCOM, (201) 328-3237, or T. Gutch, MPBMA, (201)328-4084.

Project 4349. Modernization of Press Loading for HEP Projectiles. Labor intensive loading of high explosive projectiles generates wasteful increments and machining of excess explosives. This project will develop prototype automatic increment feed system and automatic adjustment of increments for limited/or no machining of fuzz. The first increment netweigher has been installed and checked out for operation. All equipment and accessories were installed. Prototype and inert tests were completed. The press will have to be sent to another facility for live loading. For additional information, contact R. Daywalt, ARRADCOM, (317) 854-1669, or E. Feddema, MPBMA, (201) 328-4071.

Project 4364. On-Line Bio Sensors to Monitor Mixed Waste Streams. PL92-500 requires that waste discharges be monitored to assure that aquatic life is protected from toxic/hazardous substances. In addition, biological monitoring soon will be required in some national pollution discharge elimination system permits. This project will use a biological monitoring system to evaluate toxic effects. From correlations between chemical constituents in the waste water and biological responses, expensive chemical monitoring might be eliminated. For additional information, contact D. Johnson, ARRADCOM, (301) 671-2586, or K. Wong, MPBMA, (201) 328-4076.

Project 4139. Application of Radar to Ballistic Acceptance Testing of Ammunition. Present radars in use at the proving grounds have limited capability, are adaptations of tactical systems, and lack real time data processing capability. This project will develop a radar based instrumentation system for use at the proving grounds for the improved ballistic acceptance testing of ammunition, reduction of personnel, and provisior of long range project tracking capability and improved data reduction. Antenna pedestal and servo control box have been mounted and checked. A special purchase processor has been tested and the phase frequency scan antenna was installed. The system was shipped to Yuma Proving Grounds and dynamic testing using 4.2-in. mortar rounds was started. Some modifications of programs and algorithms is required. For additional information, contact J. Secko, AR—RADCOM, (201) 328-3140, or L. Casey, MPBMA, (201) 328-4071.

Project 4139. Application of Radar to Ballistic Acceptance Testing of Ammunition—ARBAT. System testing is continuing using 60mm and 81mm mortar rounds. Various target intercept modes were tested and system software was corrected and improved. Intercept and tracking performance is gradually improving. For additional information, contact J. Secko, ARRADCOM, (201) 328-3140, or L. Casey, MPBMA, (201) 328-4071.

Project 4149. Loading of 30mm ADEN/DEFA HEDP Ammunition. The loading of ammunition presently is tailored for costly low volume production and is not readily adaptable to large scale production. Projectile bodies can be made by an impact extrusion process at a significant cost savings. A blank, cup, and draw process can also be used as an alternative. The contract for the project was signed with Honeywell. Design of projected fluted liner and charge loading was finalized. A process for projectile fabrication was tested and adopted. Hot forging of shaped charge liners proved feasible. Parameters for charge pressing were set. Three hundred fluted liners were fabricated by hot forge process with close tolerances. Projectiles were

charged and scheduled for qualification tests. For additional information, contact F. Stulb, ARRADCOM, (201) 328-4851, or C. Monroe, MPBMA, (201) 328-4081.

Project 4303. Acceptance of Continuously Produced Black Powder. There is a lack of a quality assurance system in a continuous process which defines and assures reliable performance of black powder in end item use. This project will improve the accuracy and rapidity of assessment and insure desired quality by identifying and controlling all important source material and process parameters. A flame spread test device was developed, tested, and modified. Indiana AAP started characterization of special black powder samples. Static test fixtures to simulate M28B2 artillery primer, 155mm center core charge, and 8-in. propellant charge were fabricated. Preliminary tests were made and showed the fixtures were working as intended. For additional information, contact S. Blunk, ARRADCOM (201) 328-2856, or R. Collins, MPBMA (201) 328-2822.

Project 4305. Production Techniques for Improved WP 155mm Smoke Munition. Production requirement for 155mm WP XM825 has been established in FY84 and FY85, but no production facility is currently available. This project will perform manufacturing process studies to prove out the feasibility of production filling and closing of the XM825. Equipment design was completed and detail drawings for nozzles and volumetric cylinders were provided. Fabrication of components for the fill machine are complete and are being installed along with the control system. Prove-out of WP filling, closing, and leak testing was successfully completed. Two hundred rounds were filled and closed with the equipment. For additional information, contact F. Stewart, ARRADCOM, (301) 671-2863, or W. Ng, MPBMA, (201) 328-2786.

Project 4062. Auto Manufacture System for Mortar Increment Containers. Design efforts are under way at FMC Corporation for the establishment of slurry vacuum forming and paper molding based manufacturing systems and at Innova, Inc. for the establishment of an automated assembly system. The slurry vacuum forming and paper molding based manufacturing system detail packages have been completed. The assembly system design is approximately 60% complete. For additional information, contact P. Bonnett, ARRADCOM, (201) 328-5839, or C. Imbesi, MPBMA, (201) 328-2792.

Project 4064. Auto LAP Operations for 105mm Tank Cartridges. Present manual techniques used for these items are very labor intensive and lack reproducibility, while being extremely costly. This project will design an assembly system which will be capable of repetitively assembling the 105mm tank cartridges more consistently and at a cost savings. RISI Industries was awarded the contract for the development study and the design program. A practical production line system for the load and assembly of a family of 105mm tank cartridges has been designed and is in various stages of design execution and verification. For additional information, contact K. Lischick, ARRADCOM, (201) 328-4162, or L. Casey, MPBMA, (201) 328-4071.

Project 4124. Fabrication of Control Actuation System Housings. The housings used in tactical weapons control systems are the single high cost item in the system. These housings are expensive because MID volume production capabilities have not been established. This project will provide a computer numerical control (CNC) multimission center capability to produce these housings at an annual rate of 12,000 to 50,000. The project has been awarded to Chandler-Evans. Preliminary tool and fixture specifications for the 5 and 8 inch housings have been completed. The programming and package design aspects are near completion, and tool and fixture purchases have begun. For additional information, contact R. Pellen, ARRADCOM, (201) 328-3237, or T. Gutch, MPBMA, (201) 328-4084.

Project 1335. Manufacturing Technology for New Protective Mask. Fabrication of one piece plastic masks with adequate optical characteristics is difficult. Vision reduction and distortion are critical. This project will develop a manufacturing process to alleviate production problems defined by PEP effort. Manufacturing plan, plant layout, and DIPEC search were completed. Contract was awarded to Mine Safety Appliance for procurement, setup of presses, molds, and controls for pilot plant. Specification and purchase request for a lens molding and assembly clean room were prepared. Process engineering work for coating automation was completed. For additional information, contact F. Martin, ARRADCOM, (201) 328-2970.

Project 1339. Chemical Agent Detector Production Waste Disposal. A chemical agent is needed to provide the dye for use as a liquid agent detector. This project will develop an alternative manufacturing process using a noncarcinogenic intermediate in the synthesis of the B-1 dye. M8 detector paper booklets were incinerated in the chaingrate incinerator at Pine Bluff Arsenal successfully. Stack gases were monitored and indicated no organic CODS were released into the environment. For additional information, contact D. Lee, ARRADCOM, (201) 328-3912.

Project 1403. Improved Process/Substitution of Nontoxic Dyes—M18 SMK Grenades. Current dye mixes used in yellow and green smoke munitions are known to be toxic and are suspect carcinogens. This project will improve/modify process to eliminate exposure of manufacturing personnel to the toxics and/or use of substitute nontoxic dye mixes. The chemicals, grenade hardware, and fuzes were ordered and received. For additional information, contact M. Smith, ARRADCOM, (301) 671-3223, or S. Nemiroff, MPBMA, (201) 328-2786.

Project 4024. Design Development Building Prototype Auto Assembly Machine for M223 Fuze. High density items produced on hand lines with slow speed auto equipment need higher productivity with minimum capital equipment costs. This project will develop high speed automated assembly equipment to reduce capital equipment costs for large quantity production. The contract was awarded to Innova, Inc. Concept designs were reviewed and detailed designs started. The screw and weight assembly machine and the slide assembly machine designs were completed. For additional information, contact W. Badowski, ARRADCOM, (201) 328-4638, or W. Carrigan, MPBMA, (201) 328-4081.

Project 1312. Paper, Chemical Agent Detector, M8. The pulp used to manufacture M8 paper only retains up to 50 of the required dyes. This results in a significant loss of dyes and a corresponding disposal problem. This project will incorporate dye retaining aids into the pulp as it is being processed, or in with the dyes prior to putting the dyes in the pulp to effect maximum dye retention. A kinetic dispersion mill was installed and 5 gallon quantities of each dye were redispersed and diluted to 30% solids. Tests indicate that all three dyes used in M8 paper are mutagenic. A safety SOP and protective requirements were developed. Modifications to the pilot facility were made to permit work with the dyes. Paper runs to evaluate retention aids and analysis of dye retention in paper have been completed. An increase of 11.5 percent in indicator dye retention was demonstrated. For additional information, contact P. Annunziato, AR—RADCOM, (201) 328-4424.

Project 1327. Improvement/Modernization of Gas Mask Leakage Testing. The M14 testing technique is archaic, tedious, and semiquantitative. It requires undue maintenance and strain on operators to obtain reproducible test data. This project will use state of the art gas detection system (ionization detectors, electron capture, or others) to test masks. M9A1 and M17A1 masks were sent to the Southern Research Institute for use in preparing test head fixtures. Prototype testers were manufactured which demonstrated ability to detect leaks near the 0.5cc/Min. requirment. Several possible alternate aerosols were evaluated and some were found to be suitable. For additional information, contact A. Kohut, ARRAD—COM, (201) 328-3608.

Project 6350. Road Seal Test Machine. This effort has multitasks. These include studies of carburized gear case depth, residual and near surface stresses, and multifrequency eddy current inspection techniques. The MTMIS data base does not maintain data on subtasks. For additional information, contact H. Hatch, AMMRC, (617) 923-3555.

Project 0915. Group Technology Requirements Definition (Electronics). Classification, coding systems, and group technology have been developed and used for batch manufacturing of machined parts. Potential exists for applying these techniques to electronics. Through evaluation and analysis of the perceived needs for a group technology classification and coding system for electronics components, a definition of the essential parameters to which such a system should respond will be developed. For additional information, contact N. Scott, ARRADCOM, (201) 328-6430.

Project 1295. Modular Charcoal Filter Test Equipment. Charcoal filter testing equipment to provide testing capability for various chemical agents does not exist. This project will design a modular testing system for various filter systems. A concept for the facilities requirement was prepared. The CSL safety office prepared a safety site plan and obtained approval from the DOD explosive safety board. For additional information, contact R. Morrison, ARRADCOM, (201) 328-3808.

Project 6390. Program Implementation and Information Transfer. The success of the MMT program is very dependent on whether the results of MMT work are implemented. This in turn is dependent on whether information concerning the MMT technology is made available and used by concerned parties. This project will insure that the MMT results are documented and given wide distribution so as to encourage implementation. For additional information, contact R. Farrow, AMMRC, (617) 923-3521.

Project 4462. Modernization FAD for Multibase Propellants. Forced air drying process and facilities must be modified to reduce the pollution emissions and at the same time recover valuable propellant material. This project will develop recovery equipment to reduce pollution emissions and provide more efficient heating plate coils coupled with lower air velocities. About 10 propellant drying runs were conducted on M30, M30A1, and M31A1 in the modernized FAD bay. About 20% more propellant was capable of being dried than in a conventional bay. Drying tests were successfully conducted with various multibase propellants in the FAD bay. Propellant was dried in greater quantity at lower air flow rates than in a conventional bay. For additional information, contact A. Graff, ARRADCOM, (201) 328-5572, or W. Heidelberger, MPBMA, (201) 328-3651.

Project 3572. NG-Nitrate Ester Removal by Absorption/Recycle. An operating procedure for a new absorption column was modified to include new flow rates and sampling frequencies. Bench scale apparatus and supporting equipment was moved into a new approved facility. Wastewaters containing NG and DNG were passed through an absorption column containing XAD-4 resin. Preliminary hazard analysis of the nitrate ester removal system was complete. Stability tests and DTAS were performed on NG and DNG loaded resins. Four tests of the modified 2-bed downflow absorption/denitration system and evaluation of alternate denitration solutions were performed. Small lab-scale studies to obtain isotherm and denitration data on degon loaded resins was initiated. For additional information, contact W. Buckley, ARRADCOM, (201) 328-3572.

Project 4444. Body for M42/M46 Grenade. The present method of producing the body for the M46 and M42 grenade is costly. This project will determine a more economical method to produce the body for the M42 and M46 grenades. Two scopes have been prepared. The contract was awarded to Dyron Corporation, which has submitted design drawings for a one piece M46 body. For additional information, contact V. Grasso, ARRADCOM, (201) 328-4638, or P. Ng, MPBMA, (201) 328-3730.

Project 4449. Process Improveent for Composition C-4. The existing facilities which are common to the manufacture of composition B and the other RDX composition would limit the availability of these items below their MOB requirements. This project will establish new processes and methods for the manufacture of these items to minimize the impact of common operations on capacity. For additional information, contact G. Eng, ARRADCOM, (201) 328-3717, or T. Sachar, MPBMA, (201) 328-2497.

Project 4460. Continuous Mixer-Illuminant Composition Analysis and Control System. An on-line analysis and proper control of illuminant compositions prior to consolidation to insure process integrity in illuminating candle production is not available. This project will develop a prototype automatic process control for illuminant composition consisting of sodium nitrate magnesium and an organic binder. Vendor system evaluation and equipment selection are complete. X-ray fluorescence analysis was selected after testing for the facility at Longhorn AAP. It will measure Mg, $NaNO_3$, and binder to 3% in 14 minutes vs 2 hr, using the existing method. For additional information, contact R. Wolfe, ARRADCOM, (201) 328-2188, or S. Nemiroff, MPBMA, (201) 328-2786.

Project 4267. Continuous Process for Granular Composition B. The batch-wise cooling process of RDX/TNT/WAX slurry allows only a limited control of granulation. This project will develop and use a continuous process to produce granular composition B. A meeting between the coordinating organizations was held to determine initial design criteria and the steps necessary to establish a prilling tower to produce 500 lb/hr granular composition B. Drop/impact tests were performed on cast composition B charges impacting a steel plate. There were 31 drops with no incidents. Lone Star AAP was selected as site for granular composition B pilot plant facility. For additional information, contact R. Manno, ARRADCOM, (201) 328-4205, or T. Sachar, MPBMA, (201) 328-2497.

Project 4214. Pollution Engineering for 1983-85 Requirements. The Federal regulations for environmental control are changing and becoming more stringent for 1983 and 1985. This project will adopt new technology, especially in the areas of recycling and reuse of waste material, to provide conformance with 1983 and 1985 regulations. This project is an orderly transition of pollution abatement methods for propellants and explosives and is directed to meeting future standards. Refer to the four individual tasks for any changes and/or additional information regarding the project. For additional information, contact J. Swotinsky, ARRADCOM, (201) 328-4284, or K. Wong, MPBMA, (201) 328-4076.

Project 3901. Manufacture of Fluidic Amplifiers by Cold Forming. Present methods of manufacturing fluidic amplifiers are costly, as they require 100 percent inspection because of unsatisfactory repeatability in dimensions and finishes. This project will adapt the cold forming manufacturing process to the production of aluminum fluidic amplifiers. Drawings for three laminates to be fine blanked have been generated, reviewed, and accepted. Fabrication of the tooling is in progress. For additional information, contact J. Joyce, ARRCOM, (309) 794-3080.

Project 3907. MNOS Countermemory Circuit for Fuzes. There has been no production capability for the low cost, long lead time countermemory circuits for XM587. This project evaluated low cost encapsulating methods to replace expensive ceramic package for the counter circuit and ensured a production base by continued purchases of the circuits. For additional information, contact N. Doctor, HDL, (202) 394-3114, or D. Booker, MPB—MA, (201) 328-4081.

Project 4145. Control Drying in Automated SB and all Propellants. Offline analysis for moisture and volatiles makes it difficult to control a continuous drying operation since the time required for analysis is long compared to the residence time for the propellant in a continuous dryer. This project will use product temperature and/or on-line analyzers and flow meters as a basis for improved control of a continuous drying operation and reduction of the amount of offline analysis required. A survey of process instrumentation (gas chromatograph, flow recorders, etc.) has been initiated. For additional information, contact C. McIntosh, ARR—COM, (301) 328-4123, or T. Gropler, MPBMA, (201) 328-2841.

Project 4189. High Fragmentation Steel Production Process. The current production process for manufacturing HF1 projectiles is extremely expensive. Proprietary production processes developed by private industry are not available. This project will examine new and improved production processes for reduction of starting weight, machining techniques, annealing forgings, one-hit hot nosing, heat treating, and fracture toughness. About 234 forgings are made. Multiple size reduction is being attempted and preliminary machining has begun. The incorporation of a mathematical model in forging design is under way. For additional information, contact W. Sharpe, ARRAD—COM (201) 328-4123, or G. O'Brien, MPBMA, (201) 328-3730.

Project 4200. TNT Crystallizer for Large Caliber Munitions. TNT melt loading requires an optimum ratio of molten and solid TNT in the explosive mix at the time of pour. The ratio is obtained by the addition of flake TNT to a quantity of molten TNT based on operator judgment. This project will develop a device which utilizes molten TNT to generate a slurry consistency through partially controlled steady state crystallization. By close control of TNT flow rate and thermal parameters, a continuous fine grained slurry mix of proper ratio will result. For additional information, contact F. Daly, ARRADCOM, (201) 328-5839, or B. Waldman, MPBMA, (201) 328-4071.

Project 4150. New Manufacturing Processes for SAWS Ammunition. The manufacture of penetrators into ball bullets is very costly. This project will investigate skewed axis roll forming of penetrators as well as hybrid slug manufacturing and feeding methods. Cold heading also will be evaluated. Kinefac Corporation delivered 5000 roll formed penetrators for analysis. Waterbury-Ferrel delivered 1500 cold head penetrators. This project was completed with the delivery of tools for cold heading and skewed axis roll forming of the XM777 penetrators. For additional information, contact S. Kaszupski, ARRCOM, (201) 328-4687, or B. Hajduczok, MPBMA, (201) 328-2742.

Project 4281. Synthetic Natural Gas for Process Operations. A comprehensive survey of fuel requirements for process operations at RAAP was completed. An engineering evaluation of coal gasification processes and related technology is continuing. A final technical report is in the process. For additional information, contact D. Casey, ARRADCOM, (201) 328-3998, or H. Ricci, MPBMA, (201) 328-4076.

Project 4285. TNT Equivalency Testing for Safety Engineering. Present criteria for blast resistant structures is in terms of surface burst of hemispherical TNT. In structural design, to protect from the output of other energetics, the designers must have data pertinent to the material in question. By testing to generate peak pressure, possible impulse data from blast measurements of high energy materials is generated. These results are compared with the blast output of hemispherical TNT to determine the TNT equivalency of the material. For additional information, contact J. Marsicovete, ARRADCOM, (201) 328-3906, or L. Casey, MPBMA, (201) 328-4071.

Project 4288. Explosive Safe Separation and Sensitivity Criteria. Data is required to upgrade processes and material for the maximum safety of personnel and equipment against explosion propagation. Tests will be designed and conducted for explosive depth on conveyors. Vertical and horizontal position distances for the

105mm M456 Heat-T projectile was established. Test conditions for the detonator inspection machine test were established. For additional information, contact J. Marsicovete, ARRADCOM, (201) 328-3906, or L. Casey, MPBMA, (201) 328-4071.

Project 4291. Blast Effects in the Munitions Plant Environment. Most of the design effort is in the area of lace reinforced structures for closing in areas to an explosion. We must attempt to utilize common construction material. This project will study characteristics of the blast environment and determine the response of the various structural materials and elements subjected to these loadings. Report completed on blast capacity of strengthened steel buildings. This will provide data for design of economical blast resistant steel buildings. For additional information, contact J. Marsicovete, ARRADCOM, (201) 328-3906, or L. Casey, MPBMA, (201) 328-4071.

Project 4231. In-Plant Reuse of Pollution Abated Waters. More stringent standards for military unique pollutants are reflected by the 1985 goal of zero discharge. The expense of treating pollution is high and plans are to continue this reuse of treated water in other processes. This project concentrates effort in recycling of treated waste water with the ultimate goal of complying with the zero discharge guideline. The 900 (81mm mortar line), 1000 (105mm line) and 1100 (CBU line) areas at Kansas AAP were identified as practical, economical areas for recycle/reuse of pollution abated waters. Y-line (metal parts line) at Louisiana AAP was similarly identified. The analysis was completed and the water qualification criteria for eventual recycle/reuse is being generated. For additional information, contact S. Buckley, ARR—COM, (201) 328-3572, or K. Wong, MPBMA, (201) 328-4076.

Project 4298. Evaluation of Dimethylnitrosamine Disposal on HAAP B-Line. Effluent from ammonia recovery column contains significant amounts of dimethylnitrosamine (DMN). DMN is one of the EPA consent decree compounds for which water quality criteria must be provided. EPA insists on levels below 0.3 PPB. Coordination meeting held between ARRADCOM, USAMBRDL, USATHAMA, USAEHA, PBMA, and HAAP. Work effort was identified and work designated to each organization. For additional information, contact J. Buckley, ARRCOM, (201) 328-3572, or H. Ricci, MPBMA, (201) 328-4076.

Project 4309. Process Development for 120mm Tank Ammunition. Mass production in the United States of West German 120mm tank ammunition poses problems in four functional areas; metal parts, propellant, fuze, and LAP. This is a multiyear effort in four functional areas; a separate task addresses each unique problem. This MMT supports facility project in FY 83-84 and is essential to fielding the 120mm gun system on the XM1 tank in FY85. The manufacture of NC was successfully completed in the first attempt. Boiling times were related to viscosity. The loading process parameters and methods developed by the R&D loading studies were analyzed. For additional information, contact J. Mola, ARR—COM, (201) 328-2210, or LTC W. Shelton, MBPMA, (201) 328-3049.

Project 4266. Manufacturing, Inspection and Test Equipment for Magnetic Power Supply. Piezoelectric power supplies used in heat ammo have undesirable voltage generation impressed on the electrical circuits of the round (due to shock vibrations resulting during flight) which may cause prematures. This project will move the power supply from the nose of the round to inside the PIBD fuze housing and change it to a magnetic pulse generating type power supply which is unaffected by the problem of shock vibrations. The detail design of the assembly station was completed and a functional layout of the line established. For additional information, contact E. Bisson, ARRADCOM, (201) 328-5584, or W. Carrigan, MPBMA, (201) 328-4081.

Project 3532. Molten Salt Lithium-Chloride Battery. The present lead/acid and nickel/iron batteries often need recharging in order to complete an eight hour shift. This project is to establish methods for producing in quantity lithium chloride molten salt batteries. The cell and battery were redesigned to meet special needs of Army forklift program. The battery will now be constructed with felt rather than fabric BN separators in the cells. For additional information, contact E. Dowgiallo, MERADCOM, (703) 664-5309.

Project 4322. MMT Design/Characteristics of Electronic Control System for Production Facility. Uncertainty of the effect of long term storage during plant layaway on electronic control systems and the associated impact on production base lead time. This project will analyze data concerning degradation of electronic systems during periods of dormancy and develop criteria for layaway planning and future system design. A reliability prediction model for Joliet AAP and Volunteer AAP was developed and documented in a technical report. A plan has been prepared for 11 Army facilities to prepare electronic process control systems for layaway and reactivation. For additional information, contact L. Doremus, ARRCOM, (201) 328-3084, or G. DeVoe, MPBMA, (201) 328-4071.

Project 3960. Prototype Producing Equipment—Printed Circuit Boards. R&D designs experience in-process problems when transferred to large sheet multiarray commercial production. Problems include flow solderability, line width, and in-process handling. This project will fabricate prototype producing equipment for printed circuit boards using production techniques normally used in the industrial sector to assure compatibility of the TDP with mass producability. Harry Diamond Laboratory used its prototype producing equipment to verify design packages for SEAGNAT and JAMMER. They found problems while building the circuit boards and informed the design group. New plotter, exposer, developer, etcher, laminator, and component inserter were used. For additional information, contact R. Baker, HDL, (202) 394-2820, or D. Booker, MPB—MA, (201) 328-4081.

Project 3961. Improved 3-D Vibration Accept Test F/M732 M724. Current methods are costly and time consuming, rarely expose the test item to true service environments, and require three tests to account for all test axes. This project will show use of computerized 3-D vibration/shock testing as an acceptance tool to solve technical and economic test deficiencies. Test time is reduced. The system engineering definition task is under way. Specifications for the shaker system were developed and procurement of two LING systems initiated. A finite element model of the test platform was developed and a draft TDP was prepared. For additional information, contact A. Frydman, ARRCOM, (202) 394-2804, or D. Booker, MPB—MA, (201) 328-4081.

Project 4312. Injection Molding for Production Explosive Loading. Melt loading of small explosive items normally requires large surpluses of moltent explosive to obtain good filling char. Surplus riser material can be twice the amount loaded into end items. Very small items cannot be effectively melt loaded at all. This project will develop an injection molding system for filling small items with explosive charges to finished dimensions and reduce surplus explosive requirements to very low levels. Injection loading equipment for BLU 63 bomblets was designed and fabricated. About 112 BLU 63 bomblets were loaded with Composition B. The results were acceptable. For additional information contact P. Scherchock, ARRADCOM, (201) 328-4252, or M. Condit, MPBMA, (201) 328-2712.

Project 6350. Chemical Analysis of Silicon Nitride. The silicon nitride samples were examined for yttrium content by emission spectroscopy. Samples contained 14-16 percent yttrium. Silicon content was checked by atomic absorption. A method was established for fabricating "glassy disks" from a mixture of silicon nitride powder densified with either yttrium or cerium, thorium nitrate added as an internal standard, and lithium tetraborate as the fusing agent. For additional information, contact B. Strauss, AMMRC, (617) 923-3555.

Project 1353. Smoke Mix Process (Glatt). The installation of a bulk transfer system was completed. Continued evaluation of four binders on each of 4 M-19 mix colors. Continued test program to confirm formulas and to determine operational parameters in the full scale Glatt granulator. Initiated a 12 week environmental storage and long term ambient storage test. Initiated preparation of final technical report. For additional information, contact D. Garcia, ARRCOM, (501) 541-3573, or S. Nemiroff, MPBMA, (201) 328-2786.

Project 4033. Caustic Recovery From Sodium Nitrate Sludge. Holston AAP currently is losing $80 for each ton of sodium nitrate by-product sold. Sodium nitrate is extremely difficult to dispose of because of competition from other fertilizers on the market. This project will convert sodium nitrate into sodium hydroxide for reuse in spent acid recovery operations at Holston. A substantial cost benefit results by reducing the amount of new sodium hydroxide solution to be purchased. Sludge sample from Holston was analyzed and characterized. A survey found no off the shelf incinerator available. Furnace liner materials are being reviewed to establish design criteria for pilot plant. Lab studies revealed technical problems in processing sodium oxide. Three alternative processes were proposed and an economic analysis was done on each. A contract to obtain an independent analysis of the alternatives was awarded to Battelle's Columbus Laboratories. For additional information, contact G. Eng, ARRADCOM, (201) 328-3717, or A. Schafer, MPBMA, (201) 328-2243.

Project 4281. Waste Heat Recovery. Petroleum may not be available in the future to meet production requirements. This project will develop an energy saving technology to apply to AAP manufacturing functions to reduce the quantity of energy used at all levels of production. AMAF Industries was awarded a contract to perform the waste heat recovery study at Scranton AAP. A waste heat recovery evaluation was completed and a final report was prepared. It describes the technical and economical feasibility for recovering waste heat with a boiler system. Steam would be produced to meet facility steam requirements. For additional information, contact G. Scullin, ARRADCOM, (201) 328-3742, or H. Ricci, MPBMA, (201) 328-4076.

Project 4084. Opacity/Mass Emission Correlation. Forging operations for large caliber ammunition produce smoke that is regulated for both opacity and mass of the emissions. An inexpensive opacity monitor may be used to also measure the mass of the emissions from a smoke stack if properly correlated. Extensive testing at Sunflower AAP established a correlation between mass emissions and opacity. A final report has been prepared providing test procedures and results. For additional information, contact J. Clancy, ARRCOM, (201) 328-3404, or K. Wong, MPBMA, (201) 328-4076.

Project 4137. Automated Loading of Center Core Igniters. The loading of the long slender cloth bag is an area which requires high labor costs and subjects a large number of personnel to hazardous operations. This project will develop a loading station to weigh and load both the center core bag and the base pad. A preliminary scope of work was drafted. For additional information, contact N. Baron, ARR—COM, (201) 328-3269, or J. Bomengen, MPBMA, (201) 328-2763.

Project 1500. Evaluation of Industrial Capability F/Load Commercial Explosives—High Use Munitions. During mobilization there can be a short fall in availability of military explosives. Industry has many safe explosive formulations. Their applicability to military usage is unknown. Industrial capability for filling these military needs is unknown. This project will conduct a program to identify the quantities and types of commercially available explosives that could be used to supplement the Army's production capabilities during emergency production periods. The performance of munitions produced this way will be evaluated. For additional information, contact G. Cowan, ARRCOM, (309) 794-6513, or R. Lerman, MPBMA, (201) 328-2151.

Project 6682. Simulation of Ammunition Production Lines. Methods are needed for designing production lines operating in a real environment that are subject to the uncertainties associated with machine breakdowns and scheduled maintenance. This project will use a computer program to develop simulations of the operation of model line modules for production base modernization and expansion. The GENMOD program and binomial distribution method were used to simulate the metal parts production line at MSAAP for 155mm M483. The results of a buffer analysis became the criteria for evaluation of proposals for material handling equipment. For additional information, contact M. Grum, ARRADCOM, (201) 328-4389, or Y. Wong, MPBMA, (201) 328-4084.

Project 6716. Mathematical Model of Forming Operations for Artillery Design. Trial and error methods and the absence of proven automated design techniques for tooling cause unexpected failures in forming operations and delays in startup of ammunition production lines. This project will develop analytical models and automated tool design methods of critical metal forming operations. Tool designs thus generated will be tested in a production setting to verify the computer models. Proven models are applicable to current and future ITE. Mathematical modeling of the piercing, cabbaging, and blocking operation and the computer coding of these models are completed. For additional information, contact D. Booker, MPBMA, (201) 328-4081.

Project 1903. Die Cast Tailcone and One Piece Skin for BLU-96/B. Current roll forming equipment is limited to six foot lengths; the BLU-96/B skin is ten feet long and grooved. Limited experience exists in building a die for the BLU-96/B tailcone, which is 26 inches in diameter and weighs in excess of 70 pounds. This project will develop a machine that will roll form BLU-96/B skin. Will manufacture articulate die for 2000 ton die cast press and qualify prototype for IPF. Doehler-Jarvis has completed the patterns. R. D. Schultz Co. is finishing the die. Doehler-Jarvis is installing a third 3000 ton die casting machine. Kurt Manufacturing completed the components for the two roll skin rolling machine and seam welding equipment. For additional information, contact A. Gonsiska, MPBMA, (201) 328-4081.

Project 4037. Process Improvement for Plastic Bond Explosives. Present methods of producing PBX compositions are job shop oriented and uneconomical for large scale production projected in the future. This project developed new techniques of coating, drying, and packaging PBX compositions. The first attempt evaluated equipment selected for composition. Laboratory tests indicated that COMP C-4 could be dried with a belt filter with hot air applied to the top surface. It wasn't determined cost effective. For additional information, contact G. Eng, ARRADCOM, (201) 328-3717, or T. Sachar, MPBMA, (201) 328-2497.

Project 4281. Energy Recovery From Wood Waste. The feasibility study of using wood waste as an alternative energy source is complete except for the final report. The study concluded that wood waste is a viable alternative to fossil fuels at NSTL/MSAAP. ARRADCOM made a presentation to the PBMA management staff detailing the study methods and conclusions and offered some possible alternatives to apply this new technology at MSAAP. For additional information, contact D. Casey, ARRADCOM, (201) 328-3998, or H. Ricci, MPBMA, (201) 328-4076.

Project 4226. On-Line Monitors for Water Pollutants. Identification and monitoring of individual military unique effluent pollutants is required by the Water Pollutant Control Act. This project will demonstrate prototype continuous monitors developed under an R&D program by field tests on AAP wastewater effluent discharge streams. An electrochemical analyzer operated successfully under laboratory conditions. The Raman analyzer was reassembled, aligned, and operated successfully with a dilute solution of acetone in water. The hazards analysis of the instrument is nearing solution. For additional information, contact W. Buckley, ARRCOM, (201) 328-3572, or K. Wong, MPBMA, (201) 328-4076.

Project 4417. Use of Red Phosphorus in Smoke Pot Applications. Smoke produced from HC has led to some injuries and is suspected of being a carcinogen. R&D work is being done to develop a red phosphorus mix to replace HC. However, no large scale red phosphorus preparation facilities currently exist. This project will develop the technology and establish a prototype facility which will on a large scale prepare for loading the red phosphorus formulation which is developed in R&D. Completed lab scale studies of feasibility and safety of using airmix mixer. Scale up testing initiated. Muller mixer procured. For additional information, contact M. Smith, ARRCOM, (301) 671-3223, or W. Ng, MPBMA, (201) 328-2786.

Project 4454. Auto Inspection Device for Explosive Charge in Shell-CAM. The present method of inspecting loaded projectiles utilizes a standard radiographic film method. Labor and material (film) are costly. Determination of critical defect is subject to human judgment, fatigue, and error. This project will develop prototype system using a minicomputer to analyze X-ray images to automatically accept or reject groups of the filled projectiles. It will also develop a prototype filmless real-time automated inspection system. The engineer model general performance requirements have been defined. The contractor for this model has verified the requirements. The producibility difficulties associated with the engineer model detector rollimator have been resolved. For additional information, contact G. Drucker, ARRCOM, (201) 328-5496, or L. Casey, MPBMA, (201) 328-4071.

Project 4474. Dehumidified Air for Drying Single Base Propellant. Humid air requires more energy to dry single base propellant. This project will experiment with dehumidified air to save energy. Bench scale equipment for drying single base propellant with dehumidifed air has been set up and is currently being debugged. Nine drying tests on M6MP propellant for 155mm projectiles were conducted using the bench scale drying equipment. Temperature and relative humidity were varied. Test results are being evaluated and a final technical report is being written. For additional information, contact P. Mullaney, ARRCOM, (201) 328-3258, or H. Ricci, MPBMA, (201) 328-4076.

Project 4059. Optimization—Nitroguanadine in M30 Propellant. Nitroguanidine produced on the new line at Sunflower AAP is expected to have a different particle size distribution than that of the previous supplier. This may create processing problems in the new continuous automated multibase line process. This project is to qualify the nitroguanidine produced at Sunflower AAP on the CAMBL process at Radford AAP and determine if there will be any serious processing problems. Two NQ particle size monitors—one for the crystallizer slurry and one for the final product—were modified and installed. Preliminary standardization was accomplished. An on-line slurry particle size monitor was operated in conjunction with a nitroguanidine crystallizer. Output data are being correlated with data from the air permeability method required by the product specification. For additional information, contact A. Litty, ARRCOM, (201) 328-3837, or T. Caggiano, MPBMA, (201) 328-2179.

Project 4225. Red Water Pollution Abatement System. Red water produced in volume for the purification of TNT is a pollutant for which a satisfactory disposal method does not exist. The feasibility of the Sunoco Sulfite Recovery Process for the disposal of red water has been demonstrated. This project optimizes operating parameters of critical components to support an MCA project for Radford AAP. Purification tests of crude TNT were performed with contaminated sellite. A screw conveyor was successfully tested at the Bonnot Company for extruding repulper mix and slugs of dry ash. Hydrocyclone and solid bowl centrifuge tests were performed on several ash slurry compositions. A sulfite recovery process flow plan and mass/energy balances were completed and provided by the contractor. For additional information, contact W. Buckley, (201) 328-3572, or K. Wong, MPBMA, (201) 328-4076.

Project 1355. Manufacturing Plant Toxic Effluent/Emission Pretreatment. The pollutant discharge permit program requires the use of best available technology for the treatment of designated toxic wastes by 1984. Pine Bluff Arsenal Waste Treatment Facility does not employ the best available technique for these pollutants. This project will identify

manufacturing plant problem effluents/emissions and hazardous wastes and develop treatment criteria. It will also evaluate the need for added equipment and operation criteria. For additional information, contact W. Fortner, ARRCOM, (501) 541-3578, or K. Wong, MPBMA, (201) 328-4076.

Project 4061. Nitroguanidine Process Optimization. A nitroguanidine facility has been under construction at SAAP which utilizes processes not previously used commercially; it contains many recirculation and support loops, the operation of which are strongly interdependent. This project conducted process improvement procedures using nitroguanidine support equipment and installed and applied evolutionary operation to the nitroguanidine facility. A review of the process parameters was completed for all parts of the plant. Maximum and minimum operating conditions were determined. Operations of the NSE during proveout were closely followed. An interim test plan was prepared. For additional information, contact C. Lewis, ARRCOM, (201) 328-3637, or G. Kazin, MPBMA, (201) 328-2243.

Project 1354. Sludge Volume Reduction and Disposal Process Study. MCA pollution abatement facilities under construction at Pine Bluff Arsenal discharge into a settling lagoon having a five year capacity but no cleanout or sludge disposal equipment. To extend lagoon life span, sludge volume must be minimized. This project will provide a process for lagoon sludge cleanout and dewatering for landfill disposal. Volume will be reduced by preclarification and equalization to minimize chemical treatment requirements. Evaluated other treatment chemicals to reduce sludge volume. The design for preclarification/equalization was implemented into MCA-83 project for pollution abatement modification. Pilot dewatering runs yielded sludge cake dry enough for landfill disposal. The project is near completion. For additional information, contact K. Mazander, ARRCOM, (501) 541-3578, or K. Wong, MPBMA, (201) 328-4076.

Project 4210. Dry Cutting of Energetic Materials. Benite strands are cut to required lengths using a milling machine with two circular saws. This is unduly costly because of excessive handling and additional drying and inspection. This project will initiate high pressure water in form of a fine jet stream to cut benite strands. This will reduce the number of operations, eliminate bundling and tying/untying operations, and redrying will be minimized. Work on a safety site plan and review has been initiated. Hazard classification of 1.1 was established and approximately 300 lb of inert propellant simulant was prepared. Concept drawings of material handling equipment were prepared. For additional information, contact S. Lerner, ARRADCOM, (201) 328-3637, or R. Mazinski, MPBMA, (201) 328-2941.

Project 4344. Establishment of Waste Disposal Techniques for M678 Binary Project. Large quantities of solid wastes are generated during manufacturing—there is no acceptable disposal method. Drum storage is not feasible and landfill may require special preparation. This project will develop procedures for decreasing the amount of solid waste generated. Recover wastes in the form of liquid HCL which can be used in the central LWT facility and recycle still bottoms; this will reduce solid wastes by 80 percent. A review and analysis of prior DF production waste work was completed. Initiated effort on evaluation of alternative processes for waste treatment. Prepared and submitted report for review of industrial efforts of DF. For additional information, contact J. Norton, ARRADCOM, (301) 671-4286, or A. Dybacki, MPBMA, (201) 328-4076.

Project 4341. Improved Nitrocellulose Purification Process. Existing nitrocellulose purification facilities were built in the early 1940's and are in deteriorated condition. The process used dates back to WW1 and consumes large quantities of energy and water. This project will select and develop a nitrocellulose purification process to be used in the modernization program which is more energy and water efficient. The method selected is based on the Swiss conicell process as a result of the FY77 effort. Assembly of the unit is being deferred until the concrete pad is poured. For additional information, contact B. Baumann, ARRADCOM, (201) 328-4224, or D. Fair, MPBMA, (201) 328-2841.

Project 4508. Process Improvements for Pressable RDX Compositions. HSAAP is hindered with process bottlenecks in manufacturing Comp B. Processing uses job shop techniques and is labor intensive. Overall production facilities are severely constrained and operate under safety waivers due to outdated technology used. Primary bottlenecks are in the coating and drying areas. This project investigates various ways to eliminate these bottlenecks, evaluate them, and generate sufficient pilot scale data to allow design of the improved process. The final report on the Wolverine Jet Zone Dryer was issued. Composition A-7 dusting problems were eliminated by implementing the modifications recommended in the report. Remaining funds are to be used for installing and debugging the Wyssmont Turbo Dryer system. For additional information, contact G. Eng, ARRADCOM, (201) 328-3717, or P. Juergens, MPBMA, (201) 328-2243.